



OIST

June 2-5, 2026

Advances in Photoemission Techniques Workshop

Abstract Booklet

	Wednesday June 3	Thursday June 4	Friday June 5
08:10–08:50	Registration		
08:50–09:00	Opening remarks		
09:00–09:40	Ryo Noguchi	Yukiko Yamada-Takamura (online)	Andreas Santander-Syro
09:40–10:10	Taiga Nakamoto	Satoshi Ogawa	Fei Wang (online)
10:10–10:40	Coffee break		
10:40–11:20	Shunsuke Tsuda	Kyoko Ishizaka	Keshav Dani
11:20–11:50	Anup Pradhan Sakhya (online)	Suvadip Das (online)	Xing Zhu
11:50–13:20	Lunch break		
13:20–14:00	Ruotian Chen	Hongyun Zhang	Lab Tour
14:00–14:30	Yaolong Li	Sougen Furuya	
14:30–15:00	Keiki Fukumoto	Hejime Galif	
15:00–15:30	Coffee break		
15:30–16:10	Shin-ichiro Ideta (online)	Gong Chen	
16:10–16:40	Tzu Hung Chuang (online)	Makoto Kuwahara (online)	
16:40–17:10	Workshop photo	Yuichi Ishida	
17:10–17:30	Coffee break	Masaki Hada	
17:30–18:30	Poster	break	
18:30–20:00	Poster + dinner	Banquet	
20:00–20:30			

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Wednesday, June 3 (Seminar Room Lab4 E48)

08:10–08:50	Registration (Outside L4E48)
08:50–09:00	Opening remarks
09:00–09:40	Ryo Noguchi (invited) , National Taiwan University <i>Robustness of topological band structures in low-dimensional materials investigated by ARPES</i>
09:40–10:10	Taiga Nakamoto , University of Tokyo <i>Photoemission Signature of Photo-Induced Carriers and Excitons in One-Dimensional Mott Insulators</i>
10:10–10:40	Coffee break
10:40–11:20	Shunsuke Tsuda (invited) , NIMS <i>Development and Application of an imaging type Spin-Resolving Photoemission Microscope</i>
11:20–11:50	Anup Pradhan Sakhya (online) , Research Institute for Synchrotron Radiation Science, Hiroshima University <i>Rich Electronic Topography of LnTi_3Bi_4: Dirac Physics, Flat Bands, and Electronic Anisotropy</i>
11:50–13:20	Lunch break (Lab4 F44/45)
13:20–14:00	Ruotian Chen (invited) , Dalian Institute of Chemical Physics <i>Unraveling Charge-Transfer Mechanisms in Photocatalysts by Time-Resolved Photoemission Electron Microscopy</i>
14:00–14:30	Yaolong Li , Hokkaido University <i>Probing metallic and dielectric near-field modes with TR-PEEM</i>
14:30–15:00	Fukumoto Keiki , High Energy Accelerator Research Organization (KEK) <i>Operando Femtosecond Photoemission Electron Microscopy for Visualizing Carrier Motion in Semiconductor Devices</i>
15:00–15:30	Coffee break
15:30–16:10	Shin-ichiro Ideta (online) (invited) , Hiroshima University <i>Recent Developments of High-Resolution ARPES Beamlines at HiSOR and Future Plan for Upgrade</i>
16:10–16:40	Tzu Hung Chuang (online) , National Synchrotron Radiation Research Center <i>Multimodal soft X-ray photoelectron microscopy at the Taiwan Photon Source</i>
16:40–17:10	Workshop photo
17:10–17:30	Coffee Break at Lab5 D02-04 Atrium
17:30–20:00	Poster Session + dinner at Lab5 D02-04 Atrium
20:10	Taxi pickup

Thursday, June 4 (Seminar Room Lab4 E48)

09:00–09:40	Yukiko Yamada-Takamura (online) (invited) , JAIST <i>Dynamics of excitonic complexes in heavily n-doped monolayer semiconductor</i>
09:40–10:10	Satoshi Ogawa , Nagoya University <i>X-ray Photoelectron and Absorption Spectroscopy of Metal Nanoparticles</i>
10:10–10:40	Coffee break
10:40–11:20	Kyoko Ishizaka (invited) , RIKEN <i>Investigating 2D topological materials by laser micro-ARPES</i>
11:20–11:50	Suvadip Das (online) , BITS Pilani Hyderabad <i>Optical properties, Electron-phonon coupling and Spin fluctuations in 2D Quantum Materials</i>
11:50–13:20	Lunch break (Lab4 F44/45)
13:20–14:00	Hongyun Zhang (invited) , Tsinghua University <i>Flat bands engineering in rhombohedral graphene</i>
14:00–14:30	Sougen Furuya , The University of Tokyo <i>Flat-Band Superconductivity in Spinel Oxide LiTi₂O₄ Revealed by High-Resolution Laser ARPES</i>
14:30–15:00	Hejime Galif , Nagoya University/Graduate School of Engineering <i>Multimodal In-situ Characterization of Interfacial Evolution during Thermal Treatment of Co-Catalyst/Semiconductor Hybrid Photocatalysts and Its Impact on Visible-Light Activity</i>
15:00–15:30	Coffee break
15:30–16:10	Gong Chen (invited) , Nanjing University <i>Imaging and Engineering Interfacial Chirality with Spin-Polarized Low Energy Electron Microscopy</i>
16:10–16:40	Makoto Kuwahara (online) , Nagoya University <i>Photoemission electron source using a negative electron affinity surface for novel transmission electron microscopy</i>
16:40–17:10	Yuichi Ishida , Nagoya University <i>Evaluation of a high-speed electron detection camera using pulsed TEM</i>
17:10–17:40	Hada Masaki , University of Tsukuba <i>Ultrafast Structural Dynamics of Materials and Molecules Observed by Time-resolved Electron Diffraction</i>
18:30–20:30	Banquet <i>Umusan no niwa</i> <i>Excursion bus goes directly from Ocean Expo Park to dinner venue</i>
20:40	Taxi pickup

Friday, June 5 (Seminar Room Lab4 E48)

09:00–09:40	Andreas Santander-Syro (invited) , Université Paris-Saclay <i>Imaging the itinerant-to-localized transmutation of electrons across the metal-to-insulator transition</i>
09:40–10:10	Fei Wang (online) , Tsinghua university <i>Observation of Floquet-induced gap in graphene</i>
10:10–10:40	Coffee break
10:40–11:20	Keshav Dani , OIST <i>TBA</i>
11:20–11:50	Xing Zhu , OIST <i>Visualizing valleytronics of dark excitons in momentum space</i>
11:50–13:20	Lunch break (Lab4 F44/45)
13:20–14:30	Lab Tour
14:30	End of Workshop

Poster Session (Tuesday, June 2) (Lab5 D02-04)

P1	Yogendra Kumar , Research Institute for Synchrotron Radiation Science (HiSOR), Hiroshima University <i>Strain-Induced Relocation of Topological Surface States in Bi₂Se₃ Single Crystal</i>
P2	Shuto Suzuki , Tohoku University <i>Strain-induced metallic state in 1T-TaS₂</i>
P3	Jacques Hawecker , OIST <i>From 2D ferroelectricity to defect array in twisted hexagonal boron nitride</i>
P4	Yusei Morita , Tohoku university <i>Electronic structure of superconductor Pt(Bi,Se)₂ studied by high-resolution ARPES</i>
P5	Justin Wei Xiang Lim , Nanyang Technological University <i>Observing anisotropic ultrafast dynamics in bulk ReS₂ using time- and energy-resolved photoemission electron microscopy</i>
P6	Nanami Tomoda , OIST <i>Study of exciton in 2D magnetic semiconductor CrSBr using TR-ARPES</i>
P7	Gyan Prakash , OIST <i>Photoemission electron microscopy of 2D materials on plasmonic structures</i>
P8	Riyo Nagao , University of Tsukuba <i>Observation of intertube structural dynamics in carbon nanotube bundles using high coherence time-resolved electron diffraction</i>
P9	Joanna Nadolna , OIST <i>Dual-Sensitizer (Nd³⁺/Yb³⁺) Upconversion Enables Cooperative Vis-NIR Photocatalysis in NaLuF₄-Based TiO₂ Composites</i>
P10	Nagisa Yamamoto , University of Tsukuba <i>Ultrafast structural reorganization and polarization switching in ferroelectric crystals by electron diffraction</i>
P11	Yoshinori Okada , OIST <i>Spectroscopic investigation of spinel oxide superconductors</i>
P12	Fuko Kato , University of Tsukuba <i>Control techniques for pulsed electrons toward the development of a new ultrafast electron diffraction system</i>
P13	Shuta Matsuura , The University of Tokyo <i>Optical activation of a many-body exciton by antiferromagnetic order in NiPS₃</i>
P14	Kensuke Miura , University of Tsukuba <i>Improving the Resolution in Ultrafast Time-Resolved SEM Using a High-Repetition-Rate Laser</i>
P15	Maria Carla Lupu , OIST <i>Efficient high-harmonic generation at the paraxial limit driven by sub-fJ pulse energies</i>
P16	Yusuke Arashida , University of Tsukuba <i>Atomic scale ultrafast dynamics by light-field-driven scanning tunneling microscopy</i>
P17	Takemi Kato , OIST <i>Quantum-well states in highly strained alkali-metal thin films grown on Kagome metals</i>

P18	Kosuke Yoshikawa , University of Tsukuba <i>Observation of conductive holes in organic transistors using operando photoemission electron microscopy</i>
P19	Tomohito Inagaki , Graduate school of Engineering, Nagoya University <i>SEM observation of the muscle tissue of the zebrafish line overexpressing the electric eel egr3 gene</i>
P20	Harley Suchiang , OIST <i>Momentum Microscopy of Gated 2D Semiconductors</i>
P21	Masashi Nakamura , Graduate school of Engineering, Nagoya University <i>Development of a Wide-Emission-Angle Electron Gun for Performance Evaluation of an Electron Energy Analyzer</i>
P22	Takehiro Tsuchida , Graduate school of Engineering, Nagoya University <i>Application of the Serial-NED Method to Time-Resolved Transmission Electron Microscopy</i>
P23	Yuki Kobayashi , Nagoya University <i>Time-Resolved TEM Observation of Photoexcited pn-junction</i>
P24	Hayato Saeki , Nagoya University <i>Extraction and Analysis of Electronic Structure Information from EELS Using Bayesian Estimation</i>
P25	Ian Ray Lyons , OIST <i>Rich electronic reconstruction in antiferromagnetic vdW materials</i>
P26	Haruki Taira , University of Tsukuba <i>Development of Terahertz Pump and Electron Probe Setup</i>
P27	Tatsunosuke Hanano , OIST <i>Two-Color Microplasma-Based THz Radiation at MHz Repetition Rate</i>
P28	Nanako Kanno , University of Tokyo <i>Electronic structure of the skyrmion candidate materials $Gd(Ru_{1-x}Rh_x)_2Si_2$ studied by angle-resolved photoemission spectroscopy</i>
P29	Hirokazu Fujiwara , University of Tokyo <i>Latent image in resists visualized by laser-based photoemission electron microscopy</i>
P30	Masayuki Yamaoka , University of Tokyo <i>Surface Magnetization Measurement of Nb-SrTiO₃ Using PEEM</i>
P31	Takumi Fukuda , OIST <i>Ultrafast momentum dynamics of transition from free carriers into excitons in monolayer WSe₂</i>

Contributed and Invited Talks

Robustness of topological band structures in low-dimensional materials investigated by ARPES

Ryo Noguchi^{1,2}

¹ Center for Condensed Matter Sciences, National Taiwan University, Taipei 10617, Taiwan

² Center of Atomic Initiatives for New Materials, National Taiwan University, Taipei 10617, Taiwan

Email: rrnoguchi@ntu.edu.tw

Topological materials, which exhibit characteristic electronic structures such as Dirac and Weyl dispersions, have generated significant attention due to their potential applications in spintronics and quantum computing. Angle-resolved photoemission spectroscopy (ARPES) has played a central role in advancing this field by enabling the direct observation of electronic band structures. Recently, materials of lower-dimensionalities have been found to provide new platforms for exploring diverse topological quantum phenomena. In this talk, I will present our ARPES studies on low-dimensional materials to investigate the robustness of topological states.

First, we demonstrate that a robust weak topological insulator (WTI) phase can be realized in the bismuth halide $\text{Bi}_4\text{Br}_2\text{I}_2$. While $\beta\text{-Bi}_4\text{I}_4$ exhibits a WTI phase, its small band gap (< 100 meV) makes the observation of quantum transport phenomena difficult [1]. In contrast, Bi_4Br_4 shows a larger gap (~ 300 meV) but its bilayer stacking destroys the side surface states [2]. To enlarge the band gap while maintaining the WTI character, we focused on the mixed compound $\text{Bi}_4\text{Br}_2\text{I}_2$ with a three-layer stacking sequence and investigated the robustness of the topological surface states [3].

Second, we apply molecular beam epitaxy (MBE) to the investigation of magnetic topological band structures, focusing on a surface ferromagnet. Leveraging systematic polarization-dependent ARPES measurements as a function of temperature, we reveal unconventional band evolution due to the spin fluctuations, going beyond conventional band-structure descriptions [4].

References

- [1] R. Noguchi et al., *Nature* **566**, 518–522 (2019).
- [2] R. Noguchi et al., *Nat. Mater.* **20**, 473 (2021).
- [3] R. Noguchi et al., *Phys Rev. Lett.* **133**, 086602 (2024).
- [4] R. Noguchi, C. Kim et al., in preparation.

Photoemission Signature of Photo-Induced Carriers and Excitons in One-Dimensional Mott Insulators

Taiga Nakamoto¹, Yuta Murakami^{2,3}, Naoto Tsuji^{1,3}

¹ Department of Physics, The University of Tokyo, Hongo, Tokyo 113-0033, Japan

² Institute for Materials Research, Tohoku University, Sendai, 980-8577, Japan

³ RIKEN Center for Emergent Matter Science (CEMS), Wako 351-0198, Japan

Email: taiganakamoto@g.ecc.u-tokyo.ac.jp

We theoretically study photoemission spectra from photo-doped one-dimensional Mott insulators and show that their spectral characteristics differ qualitatively from those of photo-doped semiconductors. In conventional semiconductors, photoemission spectra are well understood: free charge carriers generate spectral weight near the bottom of the conduction band, while the formation of excitons leads to replica features of the valence band appearing inside the band gap. In one-dimensional Mott insulators, however, strong correlations give rise to fractionalized elementary excitations—spinons, holons, and doublons—which fundamentally modify the photoemission response. We find that when photo-doped carriers (doublons and holons) remain unbound, the photoemission spectrum directly reflects the dispersion of spinons, i.e., magnetic elementary excitations. In contrast, when a doublon and a holon form a bound excitonic state, replica structures of the lower Hubbard band emerge inside the Mott gap, carrying contributions from both spinon and holon excitations. Importantly, the distribution of the in-gap signal depends sensitively on the degree of doublon–holon binding. These results indicate that photoemission from photo-excited strongly correlated materials can provide access to magnetic properties and carrier-binding properties [1].

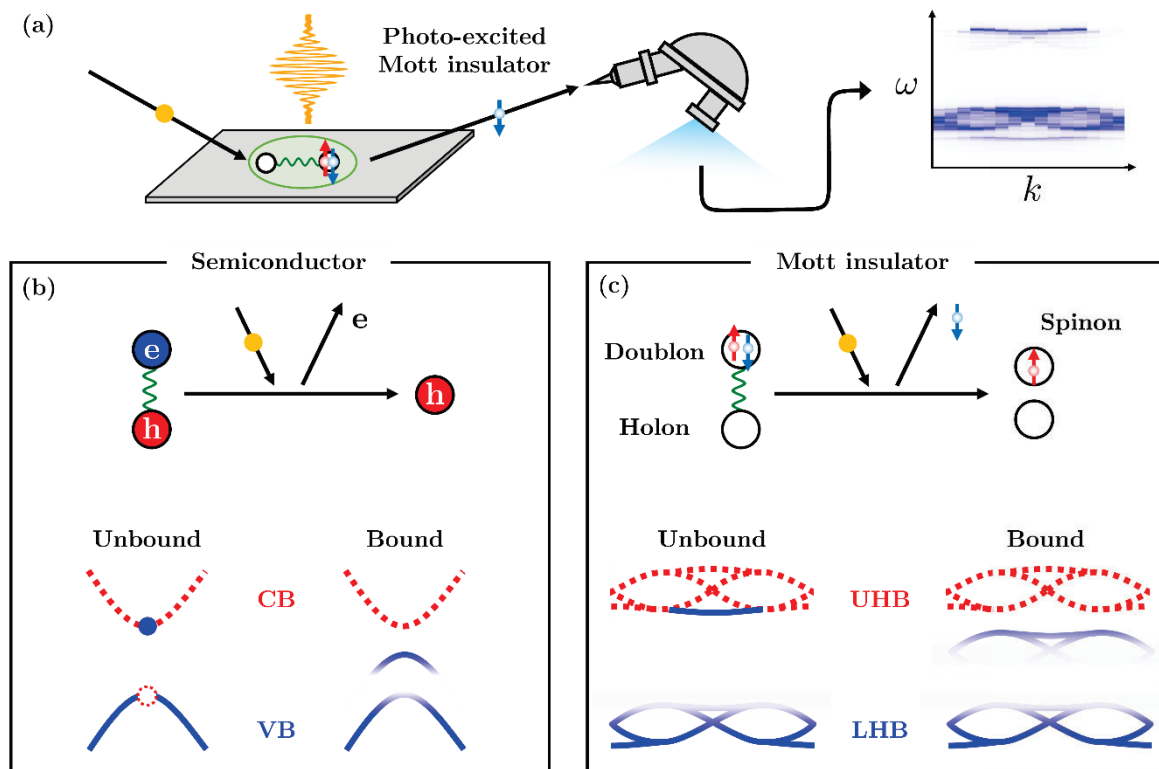


Figure 1. (a) The schematic picture of photoemission spectroscopy of the photo-excited Mott insulator. (b) (c) Schematic picture of the photoemission process and its signal in semiconductors and Mott insulators, respectively.

References

[1] T. Nakamoto, Y. Murakami, N. Tsuji, in preparation.

Development and Application of an imaging type Spin-Resolving Photoemission Microscope

Shunsuke Tsuda¹, Koichiro Yaji^{1,2}

¹National Institution for Materials Science

²UDAC, Tohoku university

Email: TSUDA.Shunsuke@nims.go.jp

Photoelectron spectroscopy has undergone a dramatic improvement in both energy and momentum resolution, and recent advances have incorporated time resolution, enabling the observation of dynamical electronic states. When combined with microscopy, the technique now achieves high spatial resolution, allowing the visualization of phenomena on sub-micrometer length scales. These developments open new opportunities in emerging fields such as quantum-material research, semiconductor devices, and energy-conversion systems, and they suggest that photoelectron spectroscopy can serve as a powerful investigative tool across a broad spectrum of scientific and technological domains.

In this workshop, we highlight the latest breakthroughs in microscopy-based photoelectron spectroscopy and the associated spectroscopic methods, presenting state-of-the-art instrumentation and representative applications. In this context, we report the development of an imaging-type spin-resolved photo-emission microscope (imaging-type Spin-resolved PhotoEmission Microscopy, hereafter iSPEM) as a microscopic platform for applying spin- and angle-resolved photoelectron spectroscopy (SARPES) to micron- and sub-micron-sized specimens.

Conventional SARPES instruments require single crystals larger than several tens of micrometers, which makes the measurement of small crystals, polycrystalline aggregates, or composition-graded thin films impractical. To overcome this limitation, iSPEM was engineered to deliver a real-space spatial resolution of ≈ 40 nm for conventional imaging and ≈ 400 nm for spin-resolved imaging^[1-3]. This high spatial resolution makes it feasible to select individual grains—typically tens to several hundred micrometers in size—within a polycrystalline sample and to perform localized ARPES and SARPES measurements.

The present contribution is organized around the proof-of-concept experiments performed with iSPEM. A polycrystalline silver specimen was used as a test sample; the real-space image (Fig. 1) clearly reveals a multitude of distinct grains. By limited the observation region by the yellow broken bar, we acquired ARPES spectra (Fig. 2) that demonstrate the ability to resolve the Fermi-surface topology of each individual grain. Moreover, the acquired spectra were further analyzed using a combination of machine-learning techniques and Gaussian-process regression, enabling the generation of photoemission spectra for unmeasured direction directly from the experimental data^[4].

These results establish a novel measurement platform that permits the direct, sub-mm scale visualization of both electronic and spin textures. The platform is expected to make a substantial contribution to the design and evaluation of next-generation electronic and spintronic materials.

References

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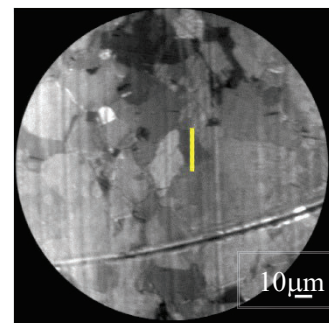


Fig. 1. real space image of polycrystalline silver

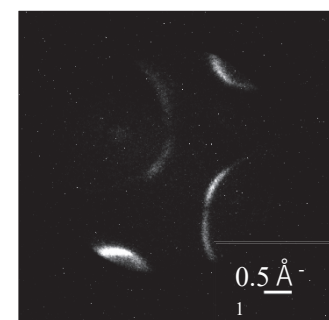


Fig. 2 photoemission intensity map of polycrystalline silver at Fermi energy

Rich Electronic Topography of $LnTi_3Bi_4$: Dirac Physics, Flat Bands, and Electronic Anisotropy

Anup Pradhan Sakhya^{1,2}, Milo Sprague¹, Mazharul Islam Mondal¹, Himanshu Sheokand¹, Arun K. Kumay¹, Brenden R Ortiz³, Nabil Atlam⁴, Matthew Matzelle⁴, Barun Ghosh^{4,5}, Arun Bansil³, Madhab Neupane¹

¹*Department of Physics, University of Central Florida, Orlando, Florida 32816, USA*

²*Research Institute for Synchrotron Radiation Science (HiSOR), Hiroshima University, Higashi-Hiroshima 739-0046, Japan*

³*Materials Science and Technology Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830, USA*

⁴*Department of Physics, Northeastern University, Boston, Massachusetts 02115, USA*

⁵*S. N. Bose National Centre for Basic Sciences, Kolkata-700106, India*

Email: anuppradhansakhya@hiroshima-u.ac.jp

Quantum materials hosting a kagome lattice, where corner-sharing triangles create a hexagonal framework, offer a distinctive platform for exploring the interplay among lattice geometry, electron correlations, and spin interactions, and have garnered significant attention in recent years [1]. In this talk, I will introduce $LnTi_3Bi_4$ (Ln = lanthanide), a new family of distorted kagome metals that has attracted interest because of the coexistence of highly anisotropic magnetism and a complex electronic structure [2]. I will present a comparative ARPES and DFT investigation of several members of this series, emphasizing their diverse yet interconnected electronic behaviors. In $YbTi_3Bi_4$, $NdTi_3Bi_4$, and $LaTi_3Bi_4$, we directly observe multiple van Hove singularities near the Fermi level, linearly dispersing Dirac-like states, and flat bands that originate from destructive interference within the Ti-based kagome network [3–5]. These features are accompanied by pronounced electronic anisotropy, reflecting the broken sixfold rotational symmetry intrinsic to the distorted kagome lattice. I will also briefly discuss $CeTi_3Bi_4$, where the Ti kagome electronic structure couples to localized Ce^{3+} moments, producing a rich magnetic phase diagram that includes a spin-density-wave ground state [6]. Taken together, these findings establish $LnTi_3Bi_4$ as a versatile model system in which flat-band physics, Dirac topology, Fermi-surface instabilities, and magnetism can be systematically investigated within a single materials family.

Acknowledgement

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Unraveling Charge-Transfer Mechanisms in Photocatalysts by Time-Resolved Photoemission Electron Microscopy

Ruotian Chen^{1,2}, Can Li¹, Keshav Dani²

¹Dalian Institute of Chemical Physics, Chinese Academy of Sciences, Dalian, China

²Okinawa Institute of Science and Technology Graduate University, Okinawa, Japan

Email: rtchen@dicp.ac.cn

Photocatalytic solar energy conversion using semiconductor particles offers a promising route toward sustainable and clean energy production. High photocatalytic performance critically depends on the efficient separation and transfer of photogenerated charge carriers to surface reaction sites. However, understanding and optimizing charge-transfer processes remain highly challenging, as they span nanometer-to-micrometer length scales and timescales from femtoseconds to much longer regimes, while involving multiple competing energy relaxation and loss pathways. In this presentation, I will introduce our work employing femtosecond time-resolved photoemission electron microscopy (TR-PEEM) to directly visualize the evolution of photogenerated electrons and holes in space, time, and energy within individual photocatalyst particles (Fig. 1), providing new insight into the origins of microscopic charge-transfer processes. We first apply TR-PEEM to a model polyhedral Cu₂O photocatalyst to map ultrafast facet-dependent electron transfer and observe inter-facet hot-electron transfer occurring on sub-picosecond timescales. Our results reveal that this sub-picosecond process originates from an unexpected quasi-ballistic mechanism, leading to anisotropic charge distributions and enhanced photocatalytic performance [1]. We then extend this approach to a practical GaN–ZnO photocatalyst that is of great interest for visible-light-driven overall water splitting. Using energy- and time-resolved PEEM, we map the spatiotemporal evolution of both electrons and holes in different electronic states within a GaN–ZnO photocatalyst particle. We reveal that efficient charge separation originates from ultrafast trapping of electrons and holes at spatially heterogeneous and energetically distinct defect states within several picoseconds, leading to long-lived charge separation up to milliseconds and enabling high-performance photocatalytic water splitting. Our work establishes PEEM as an effective approach to decipher complex charge separation mechanisms in photocatalysis.

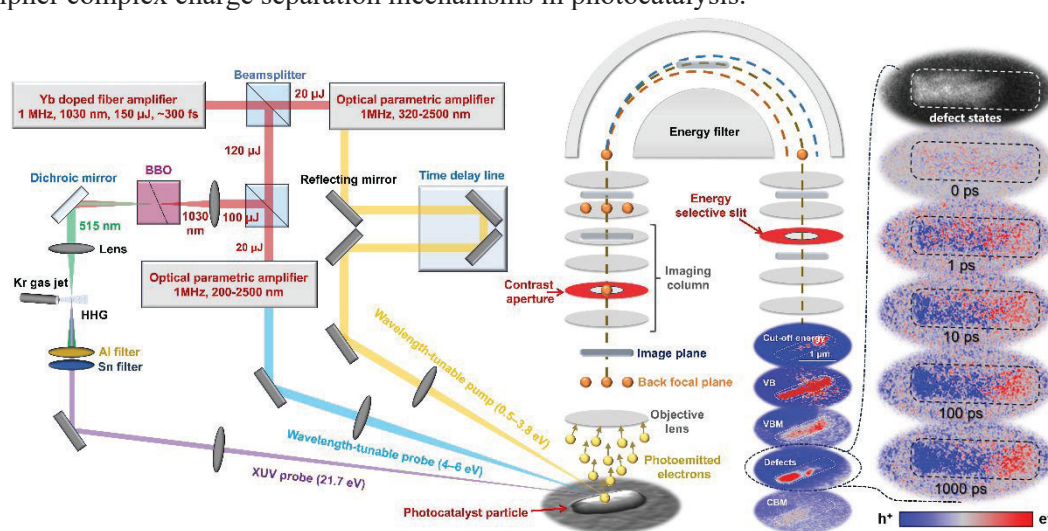


Figure 1. Schematic of spatiotemporal and energy-resolved mapping of photogenerated charge carriers in a single photocatalyst particle by time-resolved photoemission electron microscopy.

References

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Probing metallic and dielectric near-field modes with TR-PEEM

Yaolong Li^{1,2*}, Qihuang Gong¹, Hiroaki Misawa^{2,3}

Department of Physics, Peking University, Beijing 100871, China.

²*Research Institute for Electronic Science, Hokkaido University, Sapporo 001-0021, Japan.*

³*Research Institute for Interdisciplinary Science, Okayama University, Okayama 700-8530, Japan.*

Email: yaolong@pku.edu.cn

Femtosecond time-resolved photoemission electron microscopy (TR-PEEM) has broad applications in nanophotonics and surface physics due to its nano-femto spatiotemporal resolution. The applications of PEEM in nanophotonics started from surface plasmon polaritons/resonances (SPPs/SPRs) supported by metals, about twenty years ago, which have experienced successful developments. However, previous PEEM studies have mainly focused on metals, limiting the applications to a broader family of materials and modes in nanophotonics. Therefore, it is necessary to expand the scope of nanophotonic research based on PEEM. In this talk, I will present our recent work on imaging optical near-field modes of metallic and dielectric nanostructures using PEEM. This talk includes imaging dielectric ultra-confined modes supported by ZnO nanowire pairs[1], hyperbolic plasmon polaritons[2] and hyperbolic localized plasmons[3] supported by a novel van der Waals (vdW) material, MoOCl₂. These studies demonstrate that PEEM has broad prospects in the investigation of near-field optical modes beyond conventional metals.

References

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Operando Femtosecond Photoemission Electron Microscopy for Visualizing Carrier Motion in Semiconductor Devices

Keiki Fukumoto¹, Elizaveta Pyatenko^{1,2}, Kousuke Yoshikawa^{3,4}, Yoichi Yamada⁴,
Yutaka Wakayama³, Ryoma Hayakawa³

¹*Institute of Materials Structure Science, High Energy Accelerator Research Organization (KEK),
1-1 Oho, Tsukuba, Ibaraki 305-0801, Japan*

²*The Institute for Solid State Physics (ISSP), The University of Tokyo, 5-1-5 Kashiwanoha,
Kashiwa, Chiba, 277-8581, Japan*

³*Research Center for Materials Nanoarchitectonics (MANA), National Institute for Materials
Science (NIMS), 1-1 Namiki, Tsukuba, Ibaraki, 305-0044 Japan*

⁴*Institute of Pure and Applied Sciences, University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki,
305-8573 Japan*

Email: keiki@post.kek.jp

The performance of semiconductor devices such as solar cells, LEDs, and transistors is governed by the dynamics of charge carriers (electrons and holes) at p–n interfaces. We have developed a femtosecond photoemission electron microscopy (fs-PEEM) system that enables efficient detection of charge carriers in semiconductors using a photon energy-tunable fs laser source [1]. By applying this technique in an operando configuration, we have successfully visualized the depletion layer formed at semiconductor p–n junction interfaces in organic transistors [2] and GaAs-based tunnel diodes [3]. In this contribution, we introduce the experimental setup (Figure 1) and present real-space imaging of charge carrier motion and the depletion layer.

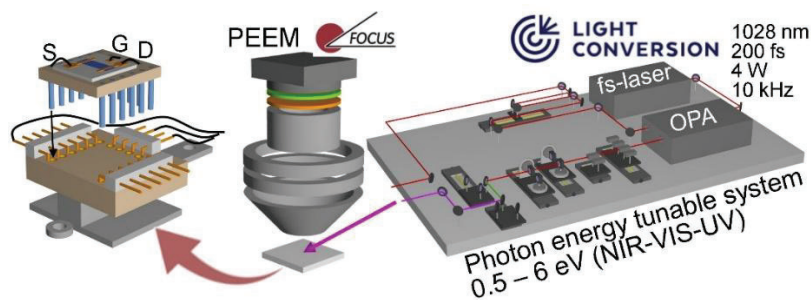


Figure 1. Schematic of the operando fs-PEEM system.

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Recent Developments of High-Resolution ARPES Beamlines at HiSOR and Future Plan for Upgrade

Shin-ichiro Ideta¹, Masashi Arita¹, Yogendra Kumar¹, Yudai Miyai^{1,2},
Shiv Kumar³, Kenya Shimada^{1,4,5}

¹ *Research Institute for Synchrotron Radiation Science, Hiroshima University, Japan*

² *KTH Royal Institute of Technology, Sweden*

³ *A*STAR Institute of Microelectronics, Singapore*

⁴ *Research Institute for Semiconductor Engineering, Hiroshima University, Japan*

⁵ *International Institute for Sustainability with Knotted Chiral Meta Matter, Hiroshima University, Japan*

Email: ideta@hisroshima-u.ac.jp

The Research Institute for Synchrotron Radiation Science is a synchrotron radiation facility established at Hiroshima University. A compact 700-MeV electron storage ring provides synchrotron radiation in the vacuum-ultraviolet (VUV) and soft x-ray regions. Tunable photon energies in this range are indispensable for studying the fine electronic structures of novel materials such as superconductors, topological insulators, and Weyl semimetals using high-resolution angle-resolved photoemission spectroscopy (ARPES).

Our facility hosts several undulator beamlines dedicated to high-resolution ARPES (BL-1 and BL-9A), enabling measurements with an energy resolution better than 5 meV. At BL-1 (high-resolution ARPES beamline, $h\nu = 23 - 350$ eV), the beam size has recently been reduced by an order of magnitude (to ~ 70 μm), and a new electron analyzer (A-1, MBS) equipped with a deflector mode has been installed to facilitate detailed measurements. A laser source has also been introduced at the endstation. These developments allow BL-1 to flexibly switch between synchrotron radiation and laser light depending on the experimental requirements, enabling highly efficient ARPES measurements. A spin-detection system will be introduced in 2026, along with new experimental apparatuses to support a wide range of research fields.

BL-9A provides low-energy-photon ARPES capabilities for solids and thin films, using synchrotron radiation in the ultraviolet region ($h\nu = 6.5 - 40$ eV). This beamline delivers high-brightness radiation with excellent energy resolution. Since October 2022, a hemispherical analyzer (ASTRAIOS 190, SPECS; acquisition angle $\pm 20^\circ$ to $\pm 30^\circ$) and a six-axis manipulator (operational temperature range: $\sim 10 - 300$ K) have been installed at the endstation. Operando measurements are also possible.

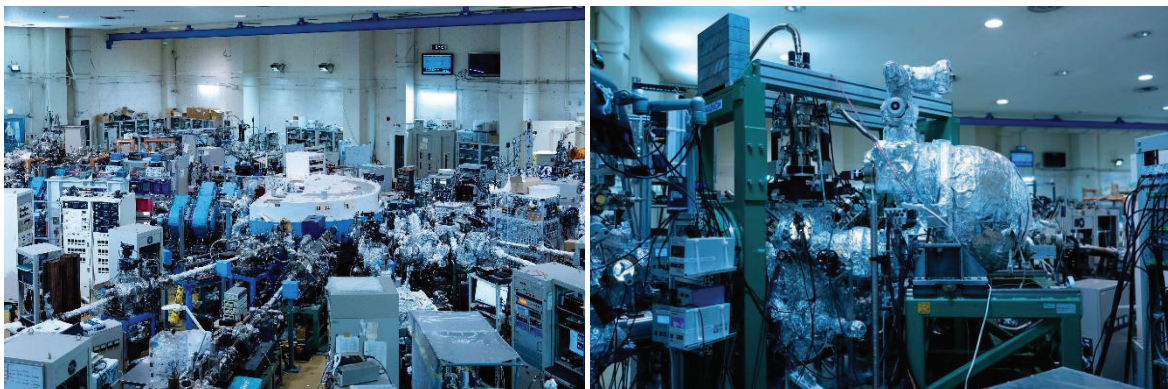


Figure 1. A compact electron-storage ring at HiSOR and the endstation of BL-1.

Acknowledgement

We acknowledge support from MEXT, Japan, and development funding for EXPERT-J provided by JST, Japan.

Multimodal soft X-ray photoelectron microscopy at the Taiwan Photon Source

Tzu-Hung Chuang^{1,*}, Heng-Wen Wei¹, Meng-Che Wu¹, Hsin-Hao Chiu¹, and Der-Hsin Wei¹

¹ National Synchrotron Radiation Research Center, Hsinchu, Taiwan

Email: chuang.th@nsrrc.org.tw

An imaging-type photoelectron momentum microscope (MM) recently established at the Taiwan Photon Source (TPS) 27A2 [1-2] is an ideal tool for probing advanced two-dimensional (2D) van der Waals (vdW) materials, taking advantages of the combination of direct-space and momentum-space imaging and photoelectron spectroscopy capabilities with both element- and spin-resolution.

Offline commissioning of the MM was performed using two in-house ultraviolet (UV) sources [2-3], and the commissioning with synchrotron soft X-rays has been initiated in mid-2025. In this talk, the performance of the MM by measuring a standard checkerboard-patterned specimen and an Au(111) single crystal using UV sources will be first presented. By analyzing the intensity profile of the edge of the Au patterns, the Rashba-splitting of Au(111) Shockley surface state at 300 K, and the photoelectron intensity across the Fermi-edge at 80 K, the spatial, momentum, and energy resolution were estimated to be 50 nm, 0.0172 \AA^{-1} and 26 meV, respectively [2]. Micro-are detection of the local band structure of a single flake of monolayered WSe₂ has been demonstrated [3].

Finally, synchrotron soft X-rays have been arrived at the 27A2 end-station in mid-2025. Recent commissioning results on imaging-based X-ray photoelectron spectroscopy (XPS), X-ray absorption spectroscopy (XAS), and X-ray magnetic circular/linear dichroism (XMCD/XMLD) will be demonstrated and discussed. Future perspectives for the multimodal operation of the soft X-ray photoelectron spectro-microscopy will also be discussed.

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Impact of Photoemission Spectroscopy on Experimental Study of Epitaxial Xenes

Yukiko Yamada-Takamura

*School of Materials Science, Japan Advanced Institute of Science and Technology (JAIST),
1-1 Asahidai, Nomi 923-1292 Ishikawa, Japan*

Email: yukikoyt@jaist.ac.jp

“Xenes” [1] are post-graphene mono-elemental two-dimensional (2D) materials represented by silicene: Si-version graphene [2]. Since silicene and most of the Xenes lack layered-structure mother crystals, they are synthesized on single crystal substrates as “epitaxial Xenes”. Crystal and electronic structures of epitaxial Xenes are often different from those predicted for their free-standing forms, and therefore, it is very important to characterize epitaxial Xenes using complementary techniques. Through close collaboration with groups specialized in photoemission spectroscopy and first-principles calculations, we have successfully demonstrated that a surface reconstruction observed on zirconium diboride (ZrB_2) thin films grown on Si(111) substrates is from silicene sheet spontaneously formed by surface-segregated Si atoms [3]. Angle-resolved [4] and core-level [5] photoemission spectroscopies, together with first-principles calculations of “unfolded” band structure [6] and absolute binding energies including final-state effect [7], have determined the details of buckling in silicene honeycomb lattice on ZrB_2 thin film and its electronic structure details. In this talk, I will introduce how photoemission spectroscopies had contributed to the characterization of epitaxial Xenes such as silicene and germanene (or 2D bitriangular lattice of Ge) [8] in our research, and how their advanced form can contribute even further.

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X-ray Photoelectron and Absorption Spectroscopy of Metal Nanoparticles

Satoshi Ogawa and Makoto Kuwahara

Institute of Materials and Systems for Sustainability (IMaSS), Nagoya University, Nagoya, Japan

Email: ogawa.satoshi.v3@f.mail.nagoya-u.ac.jp

Metal nanoparticles are attractive material for many scientific and industrial applications including catalysis and hydrogen energy materials owing to the high specific surface area and high active surface sites (edge, corner and terrace). The notable properties of nanoparticles are governed by the size, shape and electronic structure near the Fermi level. For example, Pd bulk is well known hydrogen storage material capable of absorbing the hydrogen up to 0.6 per Pd atom. In contrast, Pd nanoparticles (NPs) exhibit a reduced hydrogen absorption capacity below 0.4 H per Pd atom. The mechanism underlying the size-dependent decrease in hydrogen absorption remains poorly understood. Yamauchi et al. have suggested that the decrease of hydrogen storage capacity originates from a reduction in 4d electron holes associated with the downsizing of the crystal domain [1]. However, experimental evidence supporting this hypothesis is still insufficient. In this study, we have investigated the electronic structure of Pd NPs by soft and hard X-ray spectroscopies. Soft and hard X-ray photoelectron spectroscopy (SXPS and HAXPES) reveals the electronic state of Pd NPs at lateral surface and inside of the NPs, respectively. Moreover, X-ray absorption fine structure (XAFS) of Pd NPs has been observed to clarify the unoccupied electronic states and local structure around absorption atom.

Pd NPs were fabricated by the gas evaporation method using inert He gas [2]. The Pd NPs possess the clean surfaces because any surfactants or polymers have not been used during the fabrication process. The size and shape of Pd NPs were observed by transmission electron microscopy (TEM) at High Voltage Electron Microscope Laboratory, Nagoya University. SXPS and HAXPES measurements were performed at BL23SU and BL47XU in SPring-8, respectively. Pd L₃-edge XAFS was collected at BL6N1 in Aichi SR. All samples were fabricated and transferred without exposure to the air to avoid the surface oxidation.

Figure 1 shows TEM image of Pd NPs. The size of Pd NPs is about 5 nm and crystalline features are clearly observed. Figure 2 presents valence band spectra of Pd NPs and Pd bulk obtained by HAXPES ($h\nu=7940$ eV). DOS calculated based on DFT are also shown in Figure 2. The Density of states (DOS) of Pd bulk represent sufficiently the feature of VB spectrum of Pd bulk. The peak feature of Pd NPs appear suppressed and broadened compared with bulk one due to the variety of surface structure and size of NPs. The spectral features of Pd NPs resemble those of DOS for Pd(111) lateral surface. The valence band width is narrower and the intensity around 1.5 eV is enhanced. These characteristic difference imply the localization and modulation of 4d states near Fermi level.

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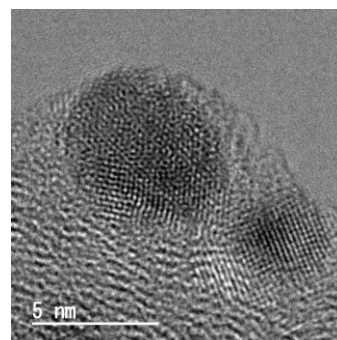


Figure 1. TEM image of Pd nanoparticles.

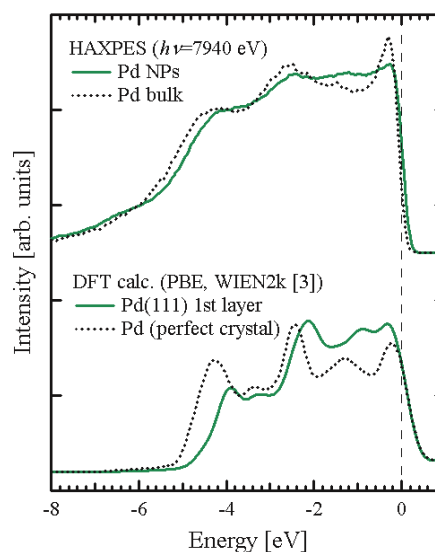


Figure 2. Valence band spectra of Pd NPs and Pd bulk obtained by HAXPES. DOS of Pd(111) and Pd crystal are also shown.

Thursday June 4

Investigating 2D topological materials by laser μ -ARPES

Kyoko Ishizaka

*Quantum-Phase Electronics Center & Department of Applied Physics, School of Engineering,
The University of Tokyo, Tokyo 113-8656, Japan
Center for Emergent Matter Science, RIKEN, Wako, Saitama 351-0198, Japan*

The diversity of atomically thin van-der-Waals materials and their stacked forms obtained through exfoliation and stamping are crucial components driving the emerging field of two-dimensional (2D) materials science. Microscopic information on their crystal structures and electronic structures is extremely important for understanding their physical properties and predicting their functions. However, thus obtained 2D materials are typically very small in size (on the micrometer scale) compared to conventional bulk materials, limiting measurement methods. Recently, we have developed techniques for laser-based micro-focused angle-resolved photoemission spectroscopy (ARPES) and transmission electron microscopy (TEM) to measure various 2D materials. In this talk, I will introduce our results on the micro-focused ARPES. The electronic band structures of atomically thin flakes for topological semimetal WTe₂ will be presented, and their layer-number- and twist-angle-dependent properties will be discussed. Additionally, I will briefly introduce our recently developed dark-field tomography method with TEM to obtain the structural information of 2D atomically thin materials, which is difficult in a normal selected area diffraction method. I will also show the unique photo-response observed in twisted Moire bilayer WSe₂ by using this method.

Thursday June 4

Optical properties, Electron-phonon coupling and Spin fluctuations in 2D Quantum Materials

Suvadip Das

Assistant Professor, Birla Institute of Technology & Science Pilani Hyderabad

Abstract

Two-dimensional quantum materials such as MoSe₂, and other transition metal dichalcogenides (TMDs) are reputed for atomically thin spintronic, valleytronic and quantum spin Hall devices. With the advent of quantum computing and superconducting devices, an exploration into the topological manifestation in 2D materials have been deemed indispensable. Functional two-dimensional materials are promising for advanced atomically thin electronic and optoelectronic devices, such as light emitting diodes (LEDs), ultrathin solar cells, and valleytronic devices. Recently, atomic layers of α -PbO and hexagonal Si/Ge have been successfully grown using micromechanical and sonochemical exfoliation. We performed first-principles calculations based on density functional theory and many-body perturbation theory to investigate the electronic and optical properties (utilizing the GW and BSE methodology) of monolayer, bilayer, and bulk layered α -PbO. Further, we have investigated the phonon lifetimes and linewidths, Gruneisen parameters and Raman modes in layered hexagonal phases of Si/Ge. A latest addition to the landscape of exotic 2D materials pertains to the discovery of not yet foretold superconducting state in monolayers of NbSe₂ dubbed 'Ising superconductivity'. In our study, we have investigated the energetics, magnetic moment and fully q-dependent spin susceptibility in order to pin point the location of the ferromagnetic instability in the Brillouin Zone of this material. This involves our methodology of inverting the random-phase approximation, and utilization of first principles calculations artificially stabilized by Hubbard interactions and spin-spiral calculations for evaluation of the fluctuation renormalized spin susceptibility. Finally the role of spin fluctuations and electron phonon coupling in determining the superconducting order parameter for the newly popular 2D Ising superconductor NbSe₂ will be discussed.

Flat bands engineering in rhombohedral stacked graphene

Hongyun Zhang^{1,2}, Jinxi Lu¹, Shuyun Zhou¹

¹ Department of Physics, Tsinghua University, P.R. China

² Advanced Institute for Materials Research (WPI-AIMR), Tohoku University, Sendai, Japan

Email: zhanghy.2015@tsinghua.org.cn

Twisting and stacking are two important control knobs for engineering topological flat bands in van der Waals heterostructures, enabling rich quantum phenomena such as unconventional superconductivity, correlated insulating and metallic states, and more recently, the fractional quantum anomalous Hall effect (FQAHE). Direct resolving the flat band is therefore critical for understanding the fundamental physics. In this talk, I will present our recent progress on flat band engineering in twisted [1-2] and stacked graphene systems [3-4] using nanospot angle-resolved photoemission spectroscopy (NanoARPES). We observe topological surface flat bands in rhombohedral-stacked graphite (RG), protected by bulk helical Dirac nodal lines. More interestingly, in pentalayer rhombohedral graphene (R5G) aligned with hexagonal boron nitride, where FQAHE emerges, we directly resolve the topological flat band and extract key hopping parameters that determine the fundamental electronic structure of rhombohedral graphene. Furthermore, by comparing aligned and non-aligned samples, we demonstrate that the moiré potential plays a pivotal role in enhancing the topological flat band in the aligned system (Fig. 1). Our results provide direct guiding lines to narrow down the phase space and establish an important foundation for understanding exotic quantum phenomena in this emerging platform.

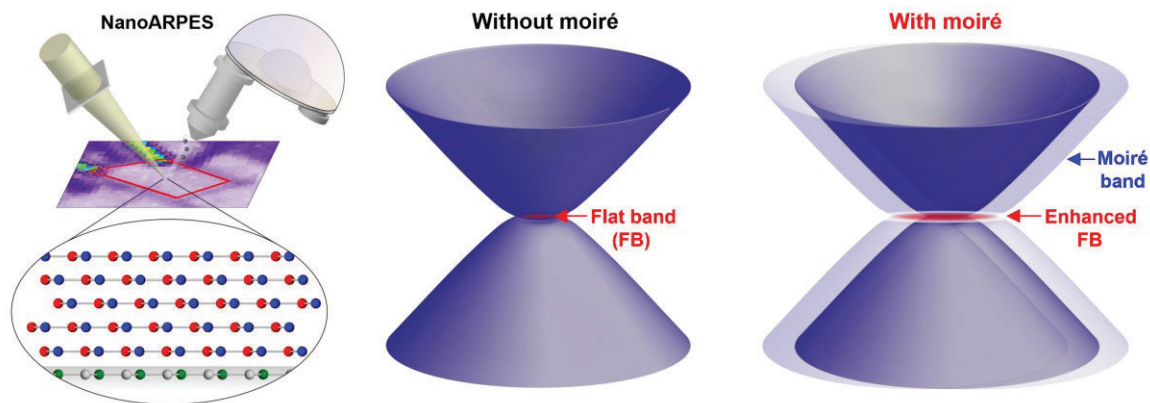


Figure 1. Moiré-enhanced flat bands in rhombohedral graphene revealed by NanoARPES.

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Flat-Band Superconductivity in Spinel Oxide LiTi_2O_4 Revealed by High-Resolution Laser ARPES

Sougen Furuya¹, Kaishu Kawaguchi¹, A. Mine¹, Shoji Arita², Chandan De³,
Dyon van Dinter³, Takemi Kato³, Hirokazu Sato³, Fumio Komori¹, Kouzou Okazaki¹,
Yoshinori Okada³, Takeshi Kondo¹

¹ISSP, The Univ. of Tokyo, Chiba 277-8581, Japan

²HiSOR, Hiroshima 739-0046, Japan

³OIST, Okinawa 904-0495, Japan

Email: furuya-sougen819@g.ecc.u-tokyo.ac.jp

The interplay between electron-electron and electron-phonon interactions is a central issue in understanding unconventional superconductivity. LiTi_2O_4 (LTO), the only known superconducting spinel oxide, provides a unique platform to investigate this problem. In LTO, Ti atoms with an average $3d^{0.5}$ configuration form a geometrically frustrated pyrochlore lattice, where electron correlations are expected to be enhanced. Although superconductivity in LTO has long been described within a conventional BCS framework dominated by electron-phonon coupling [1-3], its relatively high transition temperature ($T_c \sim 13$ K) and the absence of magnetic order suggest a more intricate mechanism. Recent theoretical and experimental studies have proposed a polaronic ground state arising from cooperative electron-electron and electron-phonon interactions [4], with momentum-dependent coupling peaking near the L point where a van Hove singularity (vHS) resides [5]. Clarifying how these intertwined interactions shape the low-energy electronic structure requires high-resolution momentum-resolved measurements. However, detailed ARPES studies have remained scarce because LTO lacks a natural cleavage plane, making it challenging to obtain clean surfaces suitable for spectroscopy.

In this study, we grew (111)-oriented thin films (~ 200 nm thick) of LTO by pulsed laser deposition and performed high-resolution ARPES using synchrotron radiation as well as 7 eV and 5.8 eV laser sources on the resulting clean surfaces. We identified a saddle point near the L point at the Brillouin zone (BZ) boundary corresponding to a vHS. In addition, we discovered a non-dispersive flat band located at the Fermi level. This flat band lies outside the Fermi surface predicted by DFT calculations and extends across nearly the entire BZ, strongly suggesting substantial electron-electron correlation effects. The spectra further exhibit a characteristic peak-dip-hump structure indicative of polaronic behavior arising from strong electron-boson coupling. We find that the quasiparticle peak disappears at the temperature where the phonon-mediated kink in the dispersion vanishes [6], revealing a close connection between quasiparticle coherence and electron-phonon interactions.

Most importantly, we directly observed the superconducting gap opening by ARPES for the first time, enabled by ultra-high energy resolution using a 5.8 eV laser source. The superconducting gap is isotropic with a magnitude of approximately 1.7 meV, consistent with previous STM measurements [3]. Our momentum-resolved measurements demonstrate that the superconducting gap opens on the flat band extending across nearly the entire BZ. These findings indicate that superconductivity in LTO is characterized by a gap opening over an unusually broad momentum range, which is highly advantageous for energy gain. The cooperative interplay between electron-electron and electron-phonon interactions, amplified by geometric frustration, therefore appears to play a central role in stabilizing superconductivity in this system with a high T_c .

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Multimodal In-situ Characterization of Interfacial Evolution during Thermal Treatment of Co-Catalyst/Semiconductor Hybrid Photocatalysts and Its Impact on Visible-Light Activity

Hejime Galif¹, Satoshi Ogawa^{1,2}, Makoto Kuwahara^{1,2}

¹Department of Energy Engineering, Graduate School of Engineering, Nagoya University, Nagoya, Japan,

²Institute of Materials and Systems for Sustainability (IMaSS), Nagoya University, Nagoya, Japan

Email: galif.hejime.b9@s.mail.nagoya-u.ac.jp

Engineering metal–semiconductor interfaces is central to overcoming band-structure limits and extending visible-light response via plasmonic coupling [1]. However, the interfacial structural evolution between plasmonic metals such as copper (Cu) and wide-bandgap semiconductors like gallium oxide (Ga₂O₃) under reductive conditions remains poorly understood due to the lack of in situ atomic-scale characterization.

Here, we establish a controlled route to build and probe the Cu/Ga₂O₃ interface by combining solution plasma process (SPP) synthesis of copper nanoparticles (CuNPs) with H₂ calcination under different temperatures (200–500 °C). The SPP pathway avoids chemical-reductant residues, rapidly yields clean metallic surfaces, and enables direct immobilization under strongly reducing conditions, promoting intimate interfacial contact.

To resolve interfacial dynamics, we performed in situ gas-environment transmission electron microscopy (TEM) (100 Pa, 1000 kV) with two workflows: (i) immediate stepwise heating in gas and (ii) vacuum pre-calcination followed by gas and stepwise heating. Because in situ EM observations can depend sensitively on beam dose and workflow history, the dual-path design discriminates intrinsic material changes from path-dependent artifacts. Coupled electron energy loss spectroscopy (EELS) and in situ X-ray absorption fine structure (XAFS) reveal a temperature-sequenced evolution: progressive reduction with maximized metallic Cu signatures near ~300 °C (highest Cu–Cu contribution in EXAFS), while higher temperatures induce partial reoxidation. We attribute the latter to near-surface decomposition of Ga₂O₃ at elevated temperatures, which provides oxygen for interfacial reoxidation of Cu, yielding distinct reconstructions across workflows. While EXAFS fitting suggests no definitive Cu–Ga alloy formation, minor alloying cannot be excluded within uncertainty.

Photocatalytic water splitting under UV and visible light shows optimal activity at ~300 °C with appropriate Cu supporting, correlating with the formation of a clean, strongly interacting Cu/Ga₂O₃ interface and plasmon-enhanced visible absorption. This work provides multiscale in situ evidence for reduction–reoxidation–reconstruction at Cu/Ga₂O₃ interfaces and offers a practical strategy for interface engineering, which is transferable to other plasmonic metal/semiconductor photocatalysts.

Acknowledgement

We thank ARAI Shigeo for kind support during the in-situ EM experiment.

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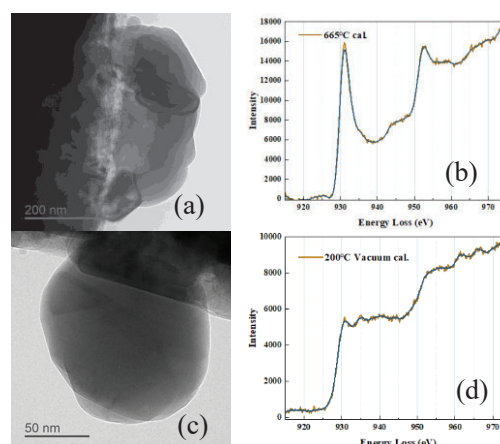


Figure 1. TEM images of Cu CuNPs. Spot A (top): (a) calcined at 665 °C; (b) corresponding EELS spectrum. Spot B (bottom): (c) calcined under vacuum; (d) corresponding EELS spectrum.

Imaging and Engineering Interfacial Chirality with Spin-Polarized Low-Energy Electron Microscopy

Gong Chen¹

¹National Laboratory of Solid State Microstructures, Department of Physics, Nanjing University, 22 Hankou Road, Nanjing 210093, People's Republic of China

Email: gch@nju.edu.cn

Spin-polarized low-energy electron microscopy (SPLEEM) provides direct real-space, vector-resolved imaging of surface magnetization in ultrathin films and establishes a quantitative approach to probe interfacial Dzyaloshinskii–Moriya interaction (DMI) in magnetic heterostructures.

This presentation summarizes recent progress in exploring interfacial DMI and chiral spin textures using SPLEEM. Interfacial DMI has commonly been associated with heavy elements possessing strong spin–orbit coupling. SPLEEM directly visualizes the evolution of chirality and enables quantitative determination of DMI. Our studies show that sizable DMI can also arise at interfaces involving light elements, including graphene [1], oxygen [2], and hydrogen [3]. At graphene/ferromagnet interfaces, DMI is linked to Rashba-type interfacial effects [1], whereas in oxygen- and hydrogen-terminated surfaces it originates from charge transfer and interfacial electric dipoles [2,3]. These mechanisms allow systematic tuning of both the magnitude and sign of DMI.

SPLEEM further resolves the internal spin structure of magnetic skyrmions and tracks their evolution under engineered DMI landscapes. Surface adsorption enables reversible skyrmion creation and deletion [4], while spatially modulated DMI supports skyrmionic textures with variable topological charge [5]. Recent work also reveals symmetry-engineered out-of-plane DMI and associated in-plane chiral textures [6]. Ongoing studies extend these approaches to layered van der Waals magnets such as $\text{Fe}_{3-x}\text{Co}_x\text{GeTe}_2$, where SPLEEM probes interlayer antiferromagnetic skyrmions and compensated topological textures [7]. These results illustrate how spin-polarized photoemission microscopy connects surface chemistry, symmetry engineering, and topological magnetism in low-dimensional systems.

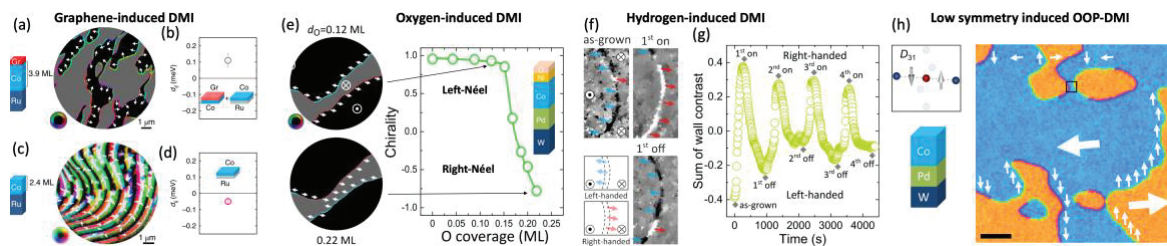


Figure 1. Direct SPLEEM imaging of engineered interfacial DMI. (a) Graphene-induced chiral domain walls via Rashba-type interfacial effects [1]. (b) Oxygen-tuned DMI and quantitative chirality evolution (Pd = 2.76 ML) [2]. (c) Hydrogen-induced DMI and reversible chirality switching [3]. (d) Symmetry-engineered out-of-plane DMI stabilizing in-plane chiral textures [6].

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Photoemission electron source using a negative electron affinity surface for novel transmission electron microscopy

Makoto Kuwahara^{1,2}, Y Kobayashi, Yuichi Ishida², Hejime Galif^{1,2}, Satoshi Ogawa^{1,2}, Takafumi Ishida^{1,2}

¹*Institute of Materials and Systems for Sustainability, Nagoya University, Nagoya 4648601, Japan*

²*Graduate School of Engineering, Nagoya University, Nagoya 4648603, Japan*

Email: kuwahara@imass.nagoya-u.ac.jp

Pulsed electron beam is a powerful tool for investigation of time-dependent phenomena in a real space, reciprocal space and energy space, which are conducted with microscopic imaging, electron beam diffraction and electron energy loss spectroscopy (EELS) respectively. Especially a transmission electron microscope (TEM) is appropriate for the time-resolved imaging because of a projection-type imaging method with a high special resolution. The pulsed electron beam is generated by chopping a continuous electron beam with a fast deflector or applying a photo-emission process which can initially emit a pulsed beam synchronized with a time-structure of driving laser. To observe ultrafast phenomena beyond a nanosecond temporal resolution, we had employed semiconductor photocathode with a negative electron affinity (NEA) surface as an electron source to generate the ultrafast bunched electrons. Time-resolved measurement requires a stroboscopic method for reversible phenomena or single-shot measurement for irreversible phenomena.

Spin-polarized pulsed TEM (SP-TEM) has been successfully developed using the NEA semiconductor photocathode (NEA-PC) in Nagoya university. Pulse beam emission in the SP-TEM was performed using a combination of the NEA-PC and an ultra-short pulse laser, which has an ability of a time-resolved measurement. The photocathode has high quantum efficiency of the order of 0.1% comparing with other metal-type photocathode, which can realize a wide range of the pulse duration from a continuous emission to a pico-second pulse emission. The SP-TEM has showed several advantages of a high brightness of $3.1 \times 10^8 \text{ A cm}^{-2} \text{ sr}^{-1}$, a narrow energy width of 114meV and a long coherence length of 200 nm due to the emission process in the NEA-PC [1, 2].

Time-resolved TEM imaging and pulsed interference fringes were conducted successfully with a stroboscopic acquisition technique. The pulsed electron beam emitted from the NEA-PC has enough coherence to realize a time-resolved holography that can observe phase information in a temporal space instead of a high current density. Although a peak brightness of the picosecond pulsed beam has limitation due to space charge effect in an acceleration field at the electron gun. Therefore, the apparatus has to been improved to create a high acceleration field to suppress the space charge effect. The high-bright pulsed-beam contributes to realize time-resolved phase imaging with both of high accuracy of phase angle and high temporal resolution.

Acknowledgement

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Evaluation of a high-speed electron detection camera using pulsed TEM

Yuichi Ishida¹, Takafumi Ishida^{1,2}, Makoto Kuwahara^{1,2}, Yasuo Arai³, Koh Saitoh^{1,2}

¹ Graduate School of Engineering, Nagoya University, Nagoya, Aichi, Japan

² Institute of Materials and Systems for Sustainability, Nagoya University, Nagoya, Aichi, Japan

³ Accelerator Laboratory, High Energy Accelerator Research Organization (KEK), Tsukuba, Ibaraki, Japan

Email: ishida.yuichi.n6@s.mail.nagoya-u.ac.jp

Transmission electron microscopy (TEM) enables us to directly observe dynamic phenomena at the nanometer scale. The most common imaging method for observing dynamic phenomena is conducted by using cameras. In this case, the temporal resolution is determined by the camera frame rate, which is typically up to sub-millisecond. Pulsed TEM can be used to observe dynamic phenomena that occur faster than the temporal resolution of conventional cameras. However, many of its applications have focused on reversible processes which can be repeatedly reproduced in TEM. To observe fast irreversible processes, such as crystal-to-amorphous structural phase transitions, we have been developing a high-speed electron detection camera using silicon-on-insulator (SOI) technology with multiple in-pixel memories, named Silicon-on-insulator for Time-Resolved Imaging in Electron Microscopy (STRIEM). The first prototype of STRIEM (STRIEM1) achieved capturing electron beam with a frame interval of 900 nanoseconds. Based on the performance evaluation of STRIEM1, we have been developing the second prototype of STRIEM (STRIEM2) to achieve higher temporal resolution and improve imaging performance. In this study, we aim to develop a dedicated readout system for STRIEM2 and evaluate its temporal resolution of STRIEM2. The STRIEM2 sensor chip consists of 50×50 pixels. The four in-pixel memories are integrated in each pixel, which enable high-speed image acquisition of four frames. In this study, we constructed the readout system, which synchronized the timing of pulsed electron beam irradiation with image acquisition. The pulsed electron beam was generated using a semiconductor photocathode installed in a pulsed TEM [2]. The acceleration voltage of electron beam was set to 30 kV.

Figure 1(a) shows the temporal profile of the pulsed laser incident on the photocathode, which corresponds to that of the pulsed electron beam. Figure 1(b) represents the exposure signal of STRIEM2. Figure 1(c) shows the pulsed convergent electron beam acquired by STRIEM2. The white bright spots in the first and third frames represent the electron beam. These results demonstrate that STRIEM2 successfully performed electron imaging synchronized with the pulsed electron beam, with an exposure time of 100 ns and a frame interval of 200 ns. In this presentation, we will also show sub-100-nanosecond time-resolved electron imaging achieved with STRIEM2.

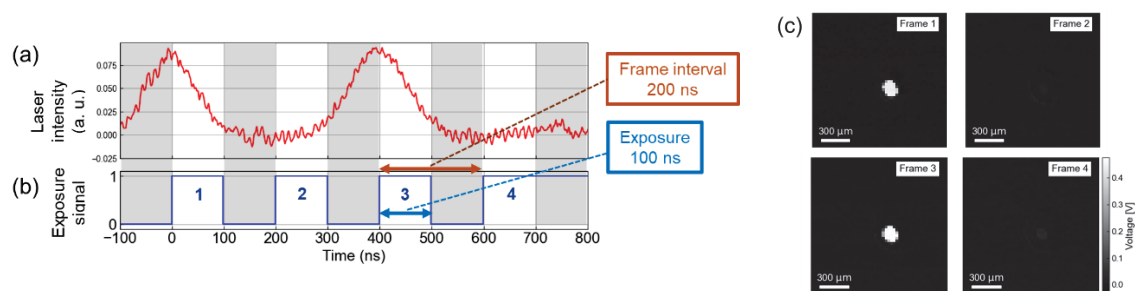


Figure 1. (a) Temporal profile of the pulsed laser corresponding to the pulsed electron beam. (b) Exposure signals of STRIEM2. (c) TEM images acquired with STRIEM2. The scale bar represents the size on the sensor plane.

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Ultrafast Structural Dynamics of Materials and Molecules Observed by Time-resolved Electron Diffraction

Haruki Taira¹, Kaito En-ya¹, Riyo Nagao¹, Fuko Kato¹, Nagisa Yamamoto¹, Shinya Koshihara², Yusuke Arashida², Gael Privault², Arnaud Arbouet^{2,3}, and Masaki Hada^{2*}

¹Graduate School of Pure and Applied Sciences, University of Tsukuba, Tsukuba, Japan.

²Institute of Pure and Applied Sciences, University of Tsukuba, Tsukuba, Japan.

³CNRS, University of Rennes, DYNACOM (Dynamical Control of Materials Laboratory)—IRL, The University of Tokyo, Tokyo, Japan

Email: hada.masaki.fm@u.tsukuba.ac.jp

Functions of materials are dictated by atomic and electronic motions that respond to external stimuli on the attosecond to nanosecond timescales. Ultrafast time-resolved measurements, primarily transient transmission and reflection measurements, have demonstrated these atomic and electronic motions, including lattice, charge, spin, and orbital dynamics, within these timescales. However, because these atomic and electronic motions interact with one another, one cannot fully capture this complexity only with the transient transmission and reflection measurements. Consequently, complementary methods, such as ultrafast spectroscopy, imaging, and diffraction techniques, are increasingly important for understanding photoinduced phenomena (Fig. 1). Our team has developed several ultrafast time-resolved electron diffraction apparatuses to investigate the photoinduced structural dynamics of inorganic materials [1], carbon nanostructures [2], and organic molecules [3,4]. One of these systems has a high transverse coherence length of approximately 10 nm, enabling the resolution of lattice spacing in biomaterials [5]. The other system, with an extremely high temporal resolution of less than 100 fs, utilizes terahertz waves as the pump light.

In this presentation, we mainly introduce a recently developed ultrafast time-resolved electron diffraction setup using terahertz wave excitation. The atomic dynamics of a transition dichalcogenide, 2H-MoTe₂ (35 nm thick, free-standing film), were investigated under a terahertz field exceeding 100 kV/cm. Shear motions of the MoTe₂ layers toward the polarization axis of the terahertz wave were identified through changes in the electron diffraction patterns. These observed results may be relevant to the elementary processes underlying the terahertz-induced phase transition from the 2H-phase to the 1T'-phase. Details of the data analysis method will also be provided.

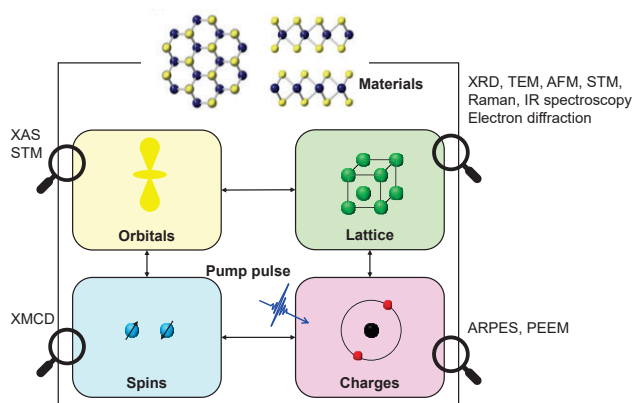


Fig. 1. The importance of probing material dynamics with complementary characterization methods.

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Imaging the itinerant-to-localized transmutation of electrons across the metal-to-insulator transition

Andrés Felipe Santander-Syro¹

¹*Institut des Sciences Moléculaires d'Orsay, Université Paris-Saclay, Orsay, France*

Email: andres.santander-syro@universite-paris-saclay.fr

The most familiar physical property of materials is their ability to conduct (metals) or not (insulators) electric current. The conductivity of metals increases when the temperature decreases. Thus, copper conducts ten times better the current at 70K than at 600K. But for V_2O_3 , a metal at room temperature, the conductivity drops sharply by a factor of a million when the temperature falls below 160K. It becomes a so-called Mott insulator! How to explain this astonishing transition? This work imaged for the first time how the itinerant, wave-like electrons in the metallic phase of V_2O_3 localize across the Mott metal-insulator transition. We will discuss the observed changes in electronic structure, and compare them with other paradigmatic examples of metal-insulator transitions.

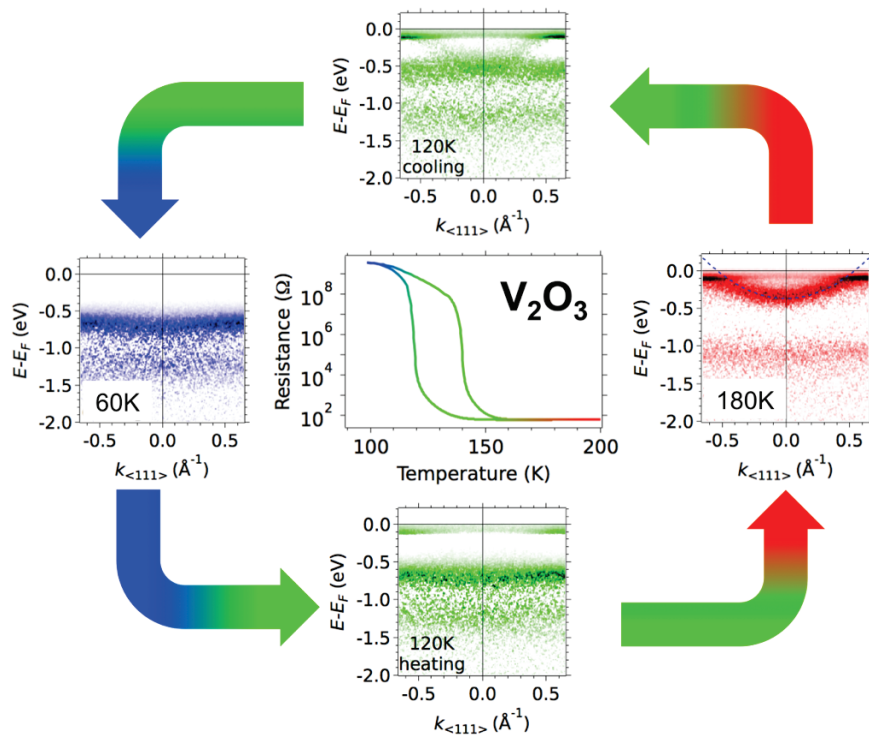


Figure 1. Changes in the electronic structure across the metal-to-insulator transition in V_2O_3 , measured using angle-resolved photoemission spectroscopy.

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Observation of Floquet-induced gap in graphene

Fei Wang¹, Xuanxi Cai¹, Shuyun Zhou^{1*}

¹ Department of Physics, Tsinghua University, P.R. China

Email: fei-wang21@mails.tsinghua.edu.cn

Floquet engineering has emerged as a powerful approach for creating non-equilibrium phases with tailored electronic structures through time-periodic light fields. Graphene serves as a unique and foundational platform for realizing Floquet band engineering, where seminal concepts such as the Floquet topological insulator and the light-induced anomalous Hall effect were first proposed [1]. Despite its central theoretical role, the most fundamental experimental signature of Floquet engineering in graphene, namely, the light-induced hybridization gap (Fig. 1), has remained elusive for over a decade.

In this talk, I will present our direct observation of the Floquet-induced gap in monolayer graphene [2]. Using time- and angle-resolved photoemission spectroscopy, we resolve a momentum-anisotropic gap opening at Floquet band crossings under resonant driving, accompanied by coherent Floquet sidebands. Remarkably, the gap hosts two Dirac nodes protected by spatiotemporal symmetry, which can be further controlled by tuning the light polarization. Our results provide a clear spectroscopic demonstration of Floquet band engineering in its original paradigm material, opening new avenues for realizing and controlling non-equilibrium quantum phases in graphene and related topological systems.

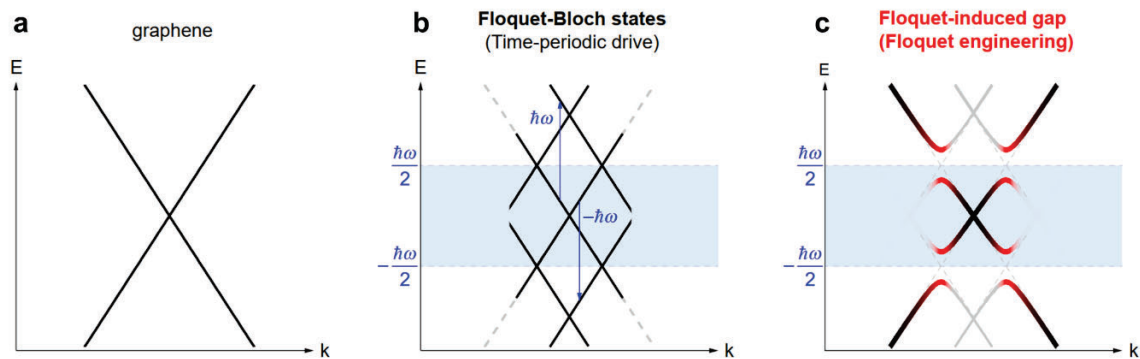


Figure 1. Schematic illustration of Floquet engineering in graphene. **a**, Dispersion of graphene. **b**, Floquet sidebands under a time-periodic drive, where $\hbar\omega$ is the driving photon energy. **c**, Floquet-induced gap through the strong light-matter interaction.

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Posters

Strain-Induced Relocation of Topological Surface States in Bi₂Se₃ Single Crystal

Y. Kumar^a, S. Kumar^a, J. Inagaki^a, S. Ideta^{a,b}, M. Arita^a, K. Kuroda^b, T. Okuda^{a,b}, K. Shimada^{a,b}

^a Research Institute for Synchrotron Radiation Science (HiSOR), Hiroshima University, Japan 739-0046

^b Graduate School of Advanced Science and Engineering, Hiroshima University, Japan 739-0046

Email: yogendra@hiroshima-u.ac.jp

Keywords: Topological insulator, in-situ strain, ARPES, Dirac point, Straintronics

To investigate the influence of strain on surface and bulk electronic states, we have developed a novel sample holder that enables *in-situ* uniaxial strain application during angle-resolved photoemission spectroscopy (ARPES) measurements at low temperatures. Using this setup, we study strain-induced modifications of the electronic band structure of Bi₂Se₃ single crystals, a prototypical layered topological insulator.

ARPES measurements reveal pronounced strain-dependent changes in both energy and momentum of the electronic states. Under tensile strain, the Dirac point shifts toward the Fermi level (lower binding energy), whereas compressive strain drives the Dirac point away from the Fermi level (higher binding energy). These results demonstrate a clear relocation and tunability of the topological surface states induced by mechanical strain. Notably, partial irreversibility of the Dirac point position is observed after strain release, suggesting possible strain-induced structural or electronic modifications.

Our study highlights the effectiveness of *in-situ* strain as a control parameter for tailoring surface and bulk electronic states in topological materials and underscores the potential of strain engineering for future straintronics applications. Furthermore, the developed strain-ARPES platform offers a versatile approach for exploring strain-driven phenomena in a wide range of layered quantum materials.

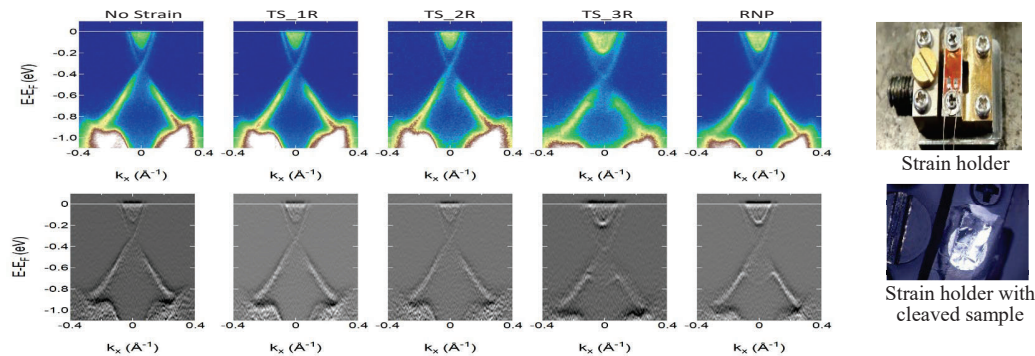


Figure 1. ARPES maps along $\bar{\Gamma} - \bar{K}$ for Bi₂Se₃ single crystal with increasing tensile strain (TS) from TS_1R to TS_2R, to TS_3R measured at 10 K with 25 eV photon energy. The DP moves to a lower energy state. The DP position was not recovered to its original position, even after removing the tensile strain (RNP).

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Strain-induced metallic state in 1T-TaS₂

Shuto Suzuki^{1*}, Kosuke Nakayama¹, Koki Yanagizawa¹, Katsuaki Sugawara^{1,2,3},
Seigo Souma^{2,4}, Kenichi Ozawa⁵, Shunichi Takano¹, Takashi Takahashi¹,
Tsutomu Nojima⁶, Keiji Ueno⁷, and Takafumi Sato^{1,2,4,8,9}

¹Department of Physics, Tohoku University, Sendai 980-8578, Japan

²WPI-AIMR, Tohoku University, Sendai 980-8577, Japan

³JST-PRESTO, Tokyo 102-0076, Japan

⁴CSIS, Tohoku University, Sendai 980-8577, Japan

⁵Institute of Materials Structure Science, KEK, Tsukuba, Ibaraki 305-0801, Japan

⁶Institute for Materials Research (IMR), Tohoku University, Sendai 980-8577, Japan

⁷Department of Chemistry, Saitama University, Saitama 338-8570, Japan

⁸SRIS, Tohoku University, Sendai 980-8577, Japan

⁹MathCCS, Tohoku University, Sendai 980-0845, Japan

*E-mail: s.suzuki@arpes.phys.tohoku.ac.jp

The layered transition metal dichalcogenide 1T-TaS₂ exhibits a variety of electronic phases depending on the temperature. Especially in low-temperature phase, it forms a characteristic superstructure known as the "Star-of-David (SoD)", becoming an insulator. 1T-TaS₂ has been extensively studied as a candidate material for Mott insulators and quantum spin liquids. Additionally, it is known to exhibit superconductivity under hydrostatic pressure and a potential metallic state under uniaxial strain [1], although its electronic state under these conditions is poorly understood. In this study, we conducted strain-applied ARPES measurements on 1T-TaS₂ to elucidate the effects of uniaxial pressure on its electronic structure.

Figure 1 shows the band dispersion along the Γ M direction measured at $T = 40$ K in unpressurized 1T-TaS₂. One can find the S $3p$ -derived bands with relatively large dispersions centered at the Γ point at higher binding energies (E_B 's) below 1.2 eV, and several Ta $5d$ -derived bands with relatively narrow energy widths within 1 eV of the Fermi level (E_F). The Ta $5d$ -derived bands exhibit a charge density wave (CDW) gap at $E_B \sim 0.3$ eV and 0.8 eV, and the insulating gap at E_F . However, under uniaxial pressure, the energy gap at E_F is suppressed, resulting in a metallic electronic structure. This finding indicates an insulator-to-metal transition induced by uniaxial pressure in 1T-TaS₂.

In the presentation, we will report on the detailed evolution of the electronic structure under uniaxial pressure and discuss the origin of the observed insulator-to-metal transition. Furthermore, we will discuss the implications of our observations in relation to the origin of the insulating phase in unpressurized 1T-TaS₂.

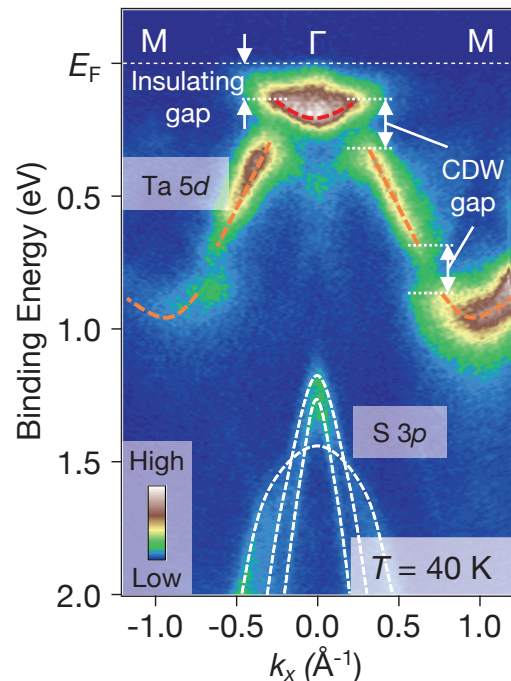


Fig.1: ARPES-intensity plot along the Γ M direction measured in the insulating phase ($T = 40$ K) in 1T-TaS₂ without uniaxial strain.

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From 2D ferroelectricity to defect array in twisted hexagonal boron nitride.

Jacques Hawecker¹, Michael K.L. Man¹, Prajakta Kokate¹, Marisa Hocking², William Millsaps², Filchito Renee G. Bagsican¹, Nanami Tomoda¹, Harley Suchiang¹, Xing Zhu¹, Amrita Mitra¹, Kenji Watanabe³, Takashi Taniguchi⁴, Julien Madéo¹, Andrew J. Mannix^{2*}, Keshav M. Dani^{1*}

¹ *Femtosecond Spectroscopy Unit, Okinawa Institute of Science and Technology Graduate University; Onna-son, Okinawa, 904-0495 Japan.*

² *Department of Materials Science and Engineering; Stanford University, Stanford, CA 94305, USA.*

³ *Research Center for Electronic and Optical Materials, National Institute for Materials Science; Tsukuba, Japan.*

⁴ *Research Center for Materials Nanoarchitectonics, National Institute for Materials Science; Tsukuba, Japan.*

Email: Jacques.hawecker@oist.jp

Deterministic nanoscale arrays of point defects are crucial for scalable quantum technologies, but current methods lack sufficient precision. We explore spatial defect distribution in twisted hBN, which exhibits moiré ferroelectricity. Photoemission electron microscopy (PEEM) reveals that defects localize at ferroelectric domain wall nodes for small domains, forming tunable nanoscale periodic arrays. For larger domains, defects align along the domain walls; photoluminescence confirms spectral signatures consistent with C-based single quantum emitters. This discovery provides a new pathway to spatially structure defects in van der Waals materials for quantum device development.

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Electronic structure of superconductor Pt(Bi,Se)₂ studied by high-resolution ARPES

Yusei Morita¹, Kosuke Nakayama¹, Naohiro Ito², Takemi Kato³, Tomonori Nakamura⁴, Hongyun Zhang^{3,5}, Xiao Tang⁵, Tianyun Lin⁵, Koki Yanagizawa¹, Seigo Souma^{3,6}, Seibun Masaki⁷, Takumi Ikushima⁷, Yuto Moriyasu⁷, Kenta Hagiwara⁸, Fumihiko Matsui^{8,9}, Kiyohisa Tanaka^{8,9}, Kenichi Ozawa¹⁰, Daisuke Shiga¹¹, Hiroshi Kumigashira¹¹, Masaki Maeda⁷, Yasuhiro Niimi^{7,12}, Takanori Kida¹³, Masayuki Hagiwara¹³, Timur K. Kim¹⁴, Cephise Cacho¹⁴, Takashi Takahashi¹, Yoshinori Okada⁴, Shuyun Zhou⁵, Takashi Koretsune¹, Kazutaka Kudo^{7,12} and Takafumi Sato^{1,3,6,15,16}

¹Department of Physics, Graduate School of Science, Tohoku University, Sendai 980-8578, Japan

²Toyota Central R&D Labs., Inc., Nagakute 480-1192, Japan

³Advanced Institute for Materials Research (WPI-AIMR), Tohoku University, Sendai 980-8577, Japan

⁴Okinawa Institute of Science and Technology Graduate University, Okinawa 904-0495, Japan

⁵State Key Laboratory of Low Dimensional Quantum Physics and Department of Physics, Tsinghua University, Beijing 100084, P. R. China

⁶Center for Science and Innovation in Spintronics (CSIS), Tohoku University, Sendai 980-8577, Japan

⁷Department of Physics, Graduate School of Science, Osaka University, Toyonaka 560-0043, Japan

⁸UVSOR Synchrotron Facility, Institute for Molecular Science, Okazaki 444-8585, Japan

⁹School of Physical Sciences, The Graduate University for Advanced Studies (SOKENDAI), Okazaki 444-8585, Japan

¹⁰Institute of Materials Structure Science, High Energy Accelerator Research Organization (KEK), Tsukuba, Ibaraki 305-0801, Japan

¹¹Institute of Multidisciplinary Research for Advanced Materials (IMRAM), Tohoku University, Sendai 980-8577, Japan

¹²Institute for Open and Transdisciplinary Research Initiatives, Osaka University, Suita 565-0871, Japan

¹³Center for Advanced High Magnetic Field Science, Graduate School of Science, Osaka University, Toyonaka, Osaka 560-0043, Japan

¹⁴Diamond Light Source, Harwell Science and Innovation Campus, Didcot, Oxfordshire OX11 0QX, UK

¹⁵International Center for Synchrotron Radiation Innovation Smart (SRIS), Tohoku University, Sendai 980-8577, Japan

¹⁶Mathematical Science Center for Co-creative Society (MathCCS), Tohoku University, Sendai 980-8578, Japan

Email: y.morita@arpes.phys.tohoku.ac.jp

Weyl semimetal PtBi₂ exhibits structural polar-nonpolar phase transition when Bi atoms are replaced by Se atoms. It has been reported that the superconducting transition temperature T_c increases significantly with this transition [1]. In order to elucidate the correlation between superconducting properties and the underlying electronic structure, we carried out high-resolution ARPES measurements on Pt(Bi_{1-x}Se_x)₂. In Pt(Bi_{0.92}Se_{0.08})₂, we observed an isotropic Fermi surface centered at the A point and a triangular Fermi surface centered at the H point (Fig. 1), which is markedly different from that of the parent compound PtBi₂ [2]. In this talk, we will discuss the relationship between these observations and the superconducting properties.

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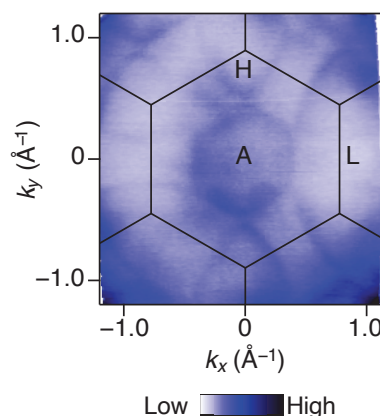


Figure 1.

Fermi surface of Pt(Bi_{0.92}Se_{0.08})₂ taken in the $k_z = \pi$ plane at $T = 40$ K.

Observing anisotropic ultrafast dynamics in bulk ReS₂ using time- and energy-resolved photoemission electron microscopy

Justin Wei Xiang Lim¹, Ruihuan Duan², Zihang Liu³, Run Long³, Zheng Liu², Oleg V. Prezhdo⁴, Zhi-Heng Loh¹

¹*School of Chemistry, Chemical Engineering and Biotechnology, Nanyang Technological University, Singapore*

²*School of Materials Science and Engineering, Nanyang Technological University, Singapore*

³*College of Chemistry, Beijing Normal University, Beijing, People's Republic of China*

⁴*Department of Chemistry and Chemical Biology, The University of New Mexico, Albuquerque, NM, USA*

Email: just0043@e.ntu.edu.sg

Semiconducting transition metal dichalcogenides (TMDs) are promising materials for applications in optoelectronic devices. The well-studied group 6 TMDs such as MoS₂, MoSe₂, WS₂ and WSe₂ possesses in-plane optically isotropic response due to the symmetric crystal lattice. In contrast, group 7 TMDs like ReS₂ display in-plane optically anisotropic response with respect to the b-axis because of their reduced crystal symmetry. The optical polarization anisotropy could be an additional tuning parameter in using TMDs for device applications.

We investigate the polarization-anisotropic carrier dynamics in bulk ReS₂ with time- and energy-resolved photoemission electron microscopy (PEEM) with sub-50-fs pump and probe pulses, and sub-200-meV energy resolution. With a bulk band gap of ~1.4 eV, the 2.41 eV pump pulses initiate above-gap excitation. Subsequently, the electron population in the conduction band is probed by the 4.81 eV probe pulses. A photoemission spectrum is obtained at each time delay (Fig. 1a). Dynamics that are dependent on both pump- and probe-polarization are revealed. When keeping the probe polarized parallel to the b-axis and at a fixed photoexcitation carrier density of $\sim 3.3 \times 10^{12} \text{ cm}^{-2}$, for example, we observe that excitation perpendicular to the b-axis results in a faster decay of $\tau_{\text{fast}}^{\perp} = 0.49 \pm 0.05 \text{ ps}$, whereas excitation parallel to the b-axis yields a slower $\tau_{\text{fast}}^{\parallel} = 1.3 \pm 0.3 \text{ ps}$ (Fig. 1b). Both cases exhibit a shared slow decay with $\tau_{\text{slow}} = 15 \pm 10 \text{ ps}$. Increasing the initial photoexcited carrier density results in a decreasing τ_{fast} , suggesting that the fast decay is a result of carrier thermalization by electron-electron scattering. With the pump polarization fixed, an additional rise component, $\tau_{\text{rise}} = 0.10 \pm 0.03 \text{ ps}$, is observed only when probing perpendicular to the b-axis (Fig. 1c). Preliminary analysis of orbital-resolved band structure calculations suggests that the broader distribution of carriers across more orbitals with components parallel to the b-axis may result in the lower probability of electron-electron interactions and therefore a slower τ_{fast} . The calculations also suggest that the rise component is likely attributed to the probing of p_y -like states as compared to p_x - and p_z - like states with different probe polarizations.

These results highlight that bulk ReS₂ demonstrates ultrafast anisotropic dynamics to linearly polarized light and could serve as a promising platform for optoelectronic device applications using light polarization as an additional tuning parameter.

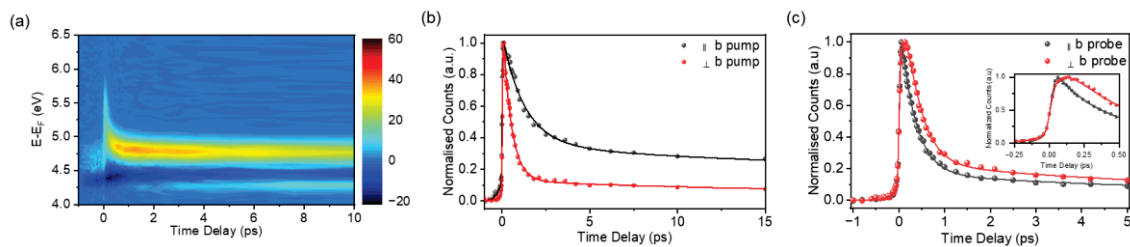


Figure 1. (a) Contour plot of photoemission spectra against time delay. (b) Time trace with fixed probe polarization along b-axis, varying pump polarization at a fixed initial carrier density. (c) Time trace with fixed pump polarization along b-axis, varying probe polarization, inset shows the early time delays.

Observation of intertube structural dynamics in carbon nanotube bundles using high coherence time-resolved electron diffraction

Riyo Nagao¹, Nagisa Yamamoto¹, Gaël Privault¹, Jun-ichi Fujita¹, Hiroo Suzuki², Yasuhiko Hayashi², Shinya Koshihara¹, Kenji Tsuruta², Arnaud Arbouet^{1,3}, Satoshi Ohmura⁴, Masaki Hada¹

¹University of Tsukuba, Ibaraki, 305-8573, Japan

²Okayama University, Okayama, 700-8530, Japan

³DYNACOM (Dynamical control of Materials Laboratory) – IRL 2015, CNRS, Univ. Rennes, Univ. Tokyo, Japan

⁴Ehime University, Ehime, 790-0825, Japan

Email: hada.masaki.fm@u.tsukuba.ac.jp

Carbon nanotubes (CNTs) are promising candidates for next-generation electronic devices because of their exceptional properties. In practical applications, CNTs are integrated into bundles or sheets where inter-tube interactions via van der Waals forces modulate their physical properties, such as thermal conductivity. Understanding these dynamics is essential for optimizing the performance of devices.

However, conventional ultrafast electron diffraction (UED) setups with plate-type photocathodes are limited by transverse coherence lengths (L_c) of only a few nanometers[1]. To resolve the periodic structure of a sample, the coherence length must exceed its periodicity. Generally, an electron beam from a virtual point-source exhibits a significantly longer L_c . We thus developed a UED setup using a 1 μm diameter tungsten tip photocathode, achieving $L_c \approx 10$ nm[2]. This enables the direct observation of intertube dynamics in bundled CNTs, where the periodicity often exceeds several nanometers. In this study, we investigated sheet samples composed of bundled CNTs aligned in parallel. The CNT sheets were probed using an ultrafast electron beam following excitation with a 515 nm pump pulse. The intertube distances in our sample ranged from 3 to 10 nm, and overlapping diffraction spots formed streak-like patterns [Fig. 1(1)]. To highlight the structural changes, we generated differential diffraction images by subtracting the unexcited data from the patterns at each delay time [Fig. 1(2)]. Photoexcitation induced a characteristic intensity decrease near the central beam and an increase in the surrounding regions, which was attributed to enhanced thermal diffuse scattering during lattice heating. Notably, a significant intensity reduction was observed in the intertube regions. This indicates that the photo-induced phonons propagate between the tubes, causing transient disordering of their alignment. By fitting the temporal evolution of this intensity change, we revealed a recovery time constant of ~ 300 ps driven by van der Waals restoring forces. This collective relaxation is consistent with the results of our molecular dynamics calculations. These observations provide crucial insights into energy dissipation and structural recovery in nanomaterial assembly.

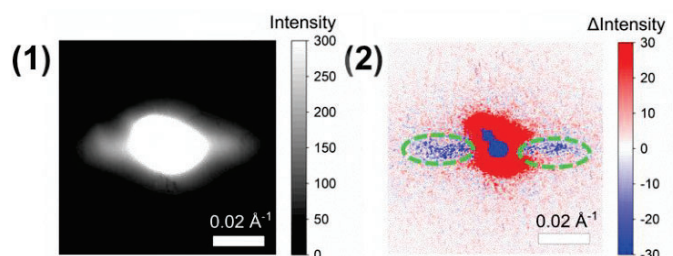


Figure 1. (1) Electron diffraction pattern of the bundled CNTs. (2) Different diffraction patterns at a delay time of 75 ps. The regions enclosed by green dotted lines correspond to the intertube diffraction, where a decrease in intensity is observed.

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Dual-Sensitizer (Nd³⁺/Yb³⁺) Upconversion Enables Cooperative Vis–NIR Photocatalysis in NaLuF₄-Based TiO₂ Composites

Joanna Nadolna^{1,2}, Ruotian Chen³, Pawel Mazierski², Zhishun Wei⁴, Tomasz Grzyb⁵,
Patrycja Szwedowska³, Prajakta Kokate¹, Keshav Dani¹

¹Okinawa Institute of Science and Technology Graduate University, Onna, Japan

²University of Gdansk, Gdansk, Poland

³Dalian Institute of Chemical Physics, Chinese Academy of Sciences, Dalian, China

⁴Hubei University of Technology, Wuhan, China

⁵Adam Mickiewicz University in Poznan, Poznan, Poland

Email: joanna.nadolna@oist.jp

Understanding how surface electronic states and energy-transfer processes influence photocatalytic activity is essential for designing materials capable of utilizing a broader portion of the solar spectrum. In particular, lanthanide-based upconversion materials offer a promising strategy for converting low-energy near-infrared (NIR) photons into higher-energy emissions capable of activating wide-bandgap semiconductors such as TiO₂. However, the contribution of upconversion processes to photocatalysis remains difficult to quantify due to complex energy-transfer pathways and limited understanding of interfacial electronic structure. In this work, NaLuF₄-based upconversion composites incorporating dual NIR sensitizers (Nd³⁺ and Yb³⁺) were integrated with TiO₂ to enable cooperative visible–NIR photocatalytic activation. The UC component consists of a NaLuF₄:Yb:Ho/NaLuF₄:Yb:Nd composite designed to absorb NIR photons at multiple wavelengths and generate higher-energy emission through multi-ion energy transfer processes. TiO₂ was deposited on the surface of the upconversion composite via a solvothermal method to form hybrid UCP–TiO₂ photocatalysts. The materials were characterized using X-ray diffraction, STEM-EDS mapping, UV–Vis diffuse reflectance spectroscopy, and X-ray photoelectron spectroscopy (XPS) to investigate surface composition, oxidation states, and lanthanide-induced defect states in TiO₂. Upconversion photoluminescence was studied under excitation at multiple NIR wavelengths (808, 975) to evaluate the efficiency of multi-sensitizer excitation pathways.

Photocatalytic activity was assessed using phenol as a colorless probe molecule to avoid dye-sensitization artifacts and enable reliable interpretation of the photocatalytic mechanism. The results reveal cooperative Vis–NIR activation of TiO₂ arising from the interplay between lanthanide-induced defect states and upconversion-mediated photon generation. Wavelength-dependent experiments demonstrate that dual Nd³⁺/Yb³⁺ sensitization enables multi-channel excitation and extends the photoresponse of TiO₂ toward the NIR region.

These findings highlight the importance of surface electronic structure and interfacial energy-transfer processes in UC-assisted photocatalysis and demonstrate how lanthanide-engineered composites can improve solar-spectrum utilization. The study provides insight into the role of defect states and multi-sensitizer excitation pathways in the design of next-generation photocatalytic materials.

Acknowledgement

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Ultrafast structural reorganization and polarization switching in ferroelectric crystals by electron diffraction

Nagisa Yamamoto¹, Weikun Zhou², Gaël Privault¹, Riyo Nagao¹, Haruki Taira¹, Fuko Kato¹, Yusuke Arashida¹, Arnaud Arbouet^{1,3}, Shinya Koshihara¹, Tsukasa Katayama², and Masaki Hada¹

¹University of Tsukuba, Ibaraki, Japan

²Hokkaido University, Hokkaido, Japan

³CNRS, University of Rennes, DYNACOM (Dynamical Control of Materials Laboratory)—IRL 2015, The University of Tokyo, Tokyo, Japan

Email: uninagi.15.25@gmail.com, hada.masaki.fm@u.tsukuba.ac.jp

It is interesting to consider femto-to-picosecond timescales and three-dimensional controls of the polarization axis of ferroelectric materials for further improvements in the performance of electric devices. Pump-probe experiments using terahertz (THz) pulses as the pump and optical pulses as the probe have been performed on strontium titanate (SrTiO₃), a perovskite oxide. Studies have demonstrated the dynamic induction of ferroelectricity in paraelectric SrTiO₃ under THz irradiation [1] and the generation of magnetization upon irradiation with circularly polarized THz pulses [2]. However, these measurements cannot distinguish between THz-induced electronic and atomic motions as the mechanisms controlling polarization and magnetization in materials. Measurements to directly observe the atomic motions in perovskite oxides are ideal for answering this question. Barium titanate (BaTiO₃), a typical ferroelectric perovskite oxide at room temperature, is widely used in electrical devices such as capacitors, thermistors, and memory devices. In this study, we chose a BaTiO₃ ultrathin film (90 nm) as the specimen for the THz pump and electron diffraction probe measurements to directly trace the atomic motions under a strong electric field.

Our developed setup, combining a THz pump and an electron diffraction probe system, generates a single-cycle THz wave with a period of ~ 1 THz and a peak electric field of 100 kV/cm at the sample position. The sample with THz irradiation was monitored using an electron pulse with a kinetic energy of 90 keV and a pulse duration of ~ 500 fs. In general, upon irradiation with a THz pulse, the lattice undergoes contraction and expansion along the direction of the THz electric field. We observed lattice elongation of approximately 0.16 % in the polarization direction of the THz pulse and a 4-5 % change in intensity of 110 and 200 diffraction spots relative to the 100 diffraction spots under the THz pulse irradiation, as shown in Fig. 1. These observations suggest the possibility of dielectric polarization switching using THz pulses on the picosecond timescale and a unique interaction between the THz wave and electrons around the Ti and O. Further insights into this phenomenon will be provided by theoretical calculations and complementary experiments.

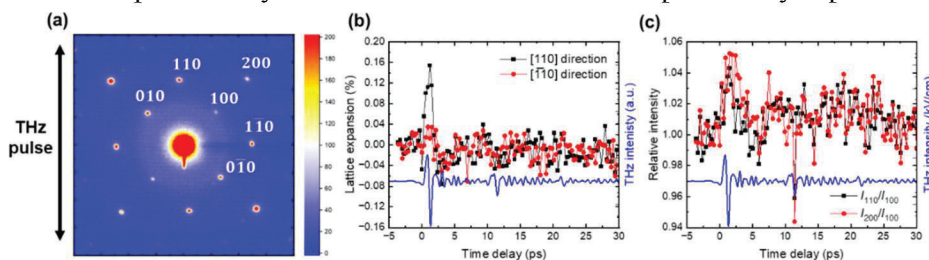


Figure 1. (a) Electron diffraction pattern of a BaTiO₃ thin film. Time evolution of the lattice expansion (b) and normalized diffraction intensity (c) induced by a THz pulse. The time trace of the incident THz wave is shown in the insets of (b) and (c).

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In-situ spectroscopic study of spinel oxide superconductor LiTi_2O_4

Yoshinori Okada

Okinawa Institute of Science and Technology (OIST)

Email: yoshinori.okada@oist.jp

Unconventional superconductivity arising from complex many-body interactions has attracted broad interest in quantum materials. In particular, the interplay between superconductivity and geometric frustration in systems such as kagome compounds and spinel oxides has become an attractive topic. In this presentation, we will discuss the exotic nature of both the normal and superconducting states in the spinel oxide LiTi_2O_4 under charge frustration by combining in situ epitaxial thin-film growth with ARPES and STM/STS.

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Control techniques for pulsed electrons toward the development of a new ultrafast electron diffraction system

Fuko Kato¹, Haruki Taira¹, Gaël Privault¹, Valentin Rollo², Yui Iwasaki¹, Riyo Nagao¹, Nagisa Yamamoto¹, Shinya Koshihara¹, Yusuke Arashida¹, Arnaud Arbouet³ and Masaki Hada¹

¹ University of Tsukuba, Tsukuba, Japan

² CEMES-CNRS, Université de Toulouse, Toulouse, France

³ CNRS, University of Rennes, DYNACOM (Dynamical Control of Materials Laboratory)—IRL, The University of Tokyo, Tokyo, Japan

Email: foucault0friko@gmail.com, hada.masaki.fm@u.tsukuba.ac.jp

Ultrafast time-resolved electron diffraction is a method for observing the structural changes of materials and molecules under photoexcitation using electron beams. The spatiotemporal control of pulsed electron beams, such as compression, acceleration, deceleration, deflection, and defocusing, has gained importance in this method. For example, the temporal resolution can be improved by compressing electron pulses [1]. An electron streak diffraction system [2] can convert temporal information into spatial information. Opto-controllable lenses (convex and concave lenses) for electron beams are also required for an extremely compact electron diffractometer and electron microscope. In this study, we developed control techniques for electron beams using radiofrequency (RF), terahertz (THz), and optical waves.

We used an ultrafast time-resolved electron diffraction system that was synchronized with an RF cavity. First, we performed compression using RF waves (frequency: 3GHz) in the RF cavity. Figure 1(a) shows the duration of the pulsed electrons after compression, demonstrating a minimum pulse duration of 200 fs. By using an RF wave, the electron pulse duration can be compressed even if the initial duration is relatively long (approximately 50 ps); therefore, we realized free control over the range from 200 fs to 50 ps. The RF cavity also controlled the ± 15 keV acceleration of 90 keV electron beams by changing the phase of the RF waves. Second, we observed electron deflection by enhanced THz waves in a metal resonator (strength: 700 kV/cm). Figure 1(b) shows the electron beam deflection at each delay time. We demonstrated that this technique is useful for developing an electron streak diffraction system. Third, we defocused the electron beam using an optical wave (pulse duration: 40 fs, center wavelength: 800 nm, fluence: 300 J/cm²). Electrons can be spatially controlled by ponderomotive interactions (oscillating waves and charged particle interactions) [3]. At the time of the laser and electron interaction, the electron beam width diverged by approximately 50 % (Figure 1(c)). From the simulation results, we can control defocusing by using the LG₀₀ laser mode and focusing by using the LG₀₁ mode [4].

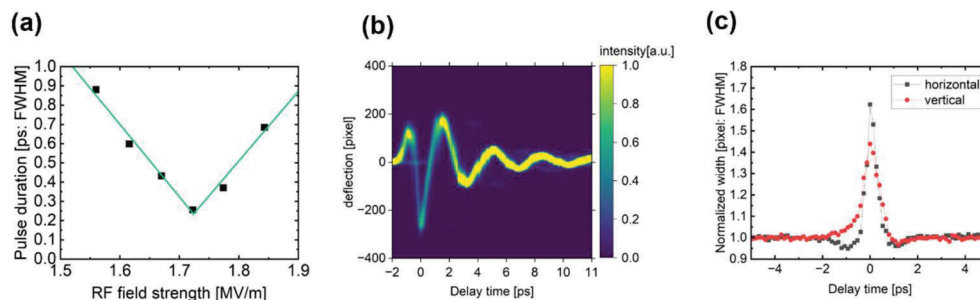


Figure 1. Control of electron pulses using electromagnetic waves (a) compression, (b) deflection, and (c) divergence.

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Optical activation of a many-body exciton by antiferromagnetic order in NiPS₃

Shuta Matsuura¹, Shohei Imai¹, Naoto Tsuji^{1,2,3}

¹*Department of Physics, University of Tokyo, Bunkyo-ku, Tokyo 113-8656, Japan*

²*RIKEN Center for Emergent Matter Science (CEMS), Wako, Saitama 351-0198, Japan*

³*Trans-scale Quantum Science Institute, University of Tokyo, Bunkyo-ku Tokyo 113-8656, Japan*

Email: matsuura@dyn.phys.s.u-tokyo.ac.jp

The discovery of intrinsic magnetism in atomically thin van der Waals (vdW) materials has opened a new regime for investigating two-dimensional magnetism and its coupling to electronic excitations [1]. A prominent example is NiPS₃, a vdW antiferromagnetic insulator, in which resonant inelastic X-ray scattering (RIXS) and optical probes (optical absorption, optical conductivity, and photoluminescence) have revealed an unusually sharp sub-gap resonance that emerges only below its Néel temperature. This coherent excitation, termed a many-body exciton, reflects intertwined charge and spin degrees of freedom and has attracted considerable attention [2]. Configuration-interaction calculations for the RIXS spectra suggest that it predominantly corresponds to a transition from a spin-triplet state to a spin-singlet state [2,3].

This raises a puzzle for linear optical response: since the optical transition is spin-conserving, a triplet-to-singlet transition should be optically dark in experiments such as optical absorption. Moreover, the microscopic origin of the strong temperature dependence, namely why the peak disappears when magnetic order is lost, has remained unclear.

Here we propose a scenario in which the many-body exciton is optically activated by the antiferromagnetic order itself. The magnetic order breaks continuous spin-rotation symmetry and mixes triplet and singlet states, generating a finite matrix element for the transition to the exciton already at the one-photon level. This mechanism naturally explains why the peak vanishes across the magnetic transition. We substantiate this scenario using a combined approach of exact diagonalization for a local cluster and the mean-field treatment of long-range antiferromagnetic order.

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Improving the Resolution in Ultrafast Time-Resolved SEM Using a High-Repetition-Rate Laser

Kensuke Miura, Jun-ichi Fujita, Yusuke Arashida

¹*Institute of pure and applied science, University of Tsukuba, Japan*

Email: arashida.yusuke.kb@u.tsukuba.ac.jp

In recent years, continued scaling of the size of semiconductor devices such as transistors has enabled higher operating speeds with more than the bandwidth of GHz however, making their performance evaluation increasingly challenging. To address this issue, we develop a scanning ultrafast electron microscopy (SUEM) system, which combines a scanning electron microscope (SEM) with a femtosecond laser [1], to visualize temporal change of electric potential on high-speed electronic devices. Time-resolved measurements of SUEM are based on a pump-probe method using optical pulses for the pump and photoelectron pulses for the probe emitted from the electron gun. Our previous setup showed that space charge effect (SCE) significantly decreases both the spatial and temporal resolution to 880 nm and 43 ps respectively. In the experiment, approximately 3000 electrons are included in an electron pulse with the repetition rate of the laser of 200 kHz. To decrease the influence of the SCE, we developed the optical setup using a laser with high repetition rate of 76 MHz.

The laser source is a mode-locked Yb:KGW oscillator with the center wavelength of 1030 nm, pulse duration of 96 fs, repetition rate of 76 MHz, and average power of 900 mW. The fourth harmonic (257 nm, 150 mW) was generated by two times of second harmonic generation and used to irradiate the electron gun for photoemission. The average current of 10 pA was derived at the sample position of the SEM which corresponds to approximately 0.8 electrons per pulse. The spatial resolution was evaluated as 92 nm by measuring a step of a gold nanostructure. The temporal resolution was evaluated as 3.7 ps. A significant improvement in these resolutions was achieved due to the reduction of SCE. These results demonstrated that employing a high-repetition-rate laser in the 10^2 MHz range is highly effective for achieving high-resolution SUEM measurements.

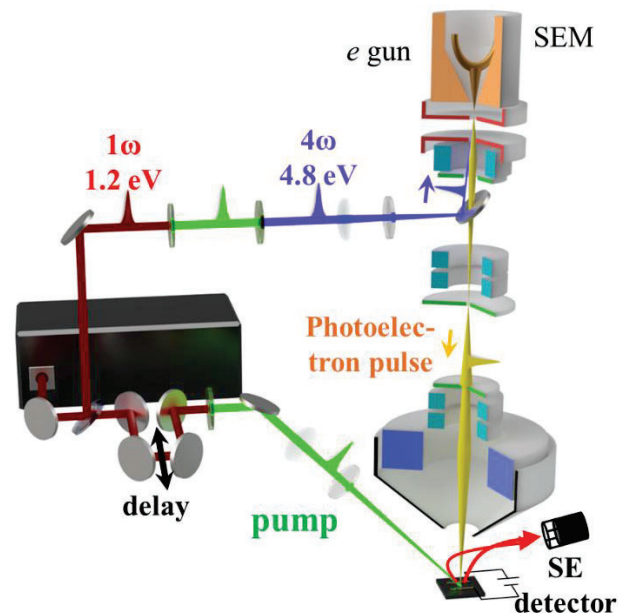


Fig. 1. Schematic of the setup of time-resolved scanning ultrafast electron microscopy using a femtosecond-laser and a SEM (JSM7200F, JEOL).

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Atomic scale ultrafast dynamics by light-field-driven scanning tunneling microscopy

Yusuke Arashida, Sou Kayano, Hiroyuki Mogi, Osamu Takeuchi, Shoji Yoshida, Hidemi Shigekawa

¹*Institute of pure and applied science, University of Tsukuba, 305-8573, Japan*

Email: arashida.yusuke.kb@u.tsukuba.ac.jp

Scanning tunneling microscopy (STM) is a powerful technique for visualizing surface topography and local electronic states with atomic-scale spatial resolution which has contributed to understand surface electronic states in thermal equilibrium [1]. Recent advances in laser technology have enabled control of the tunneling current by the electric field of light, which is called as light-field-driven STM, where the duration of optical pulse should be less than one optical cycle [2]. Terahertz (THz) pulses have been used in this technique which extends STM into the ultrafast regime on the picosecond timescale. Further improvement of the temporal resolution to study femtosecond time-scale is important to reveal nonequilibrium dynamics underlying fundamental phenomena such as electron scattering, structural phase transitions, photochemical reactions, and photoelectric conversion, *etc.*

We developed light-wave-driven STM by using broadband mid-infrared (MIR) optical pulses to improve the temporal resolution. The light source was a Ti-based optical parametric chirped pulse amplifier (OPCPA) with the wavelength range from 700 to 920 nm, the pulse duration of 8.2 fs, the repetition frequency of 4 MHz, and the pulse energy of 1 μ J. The beam was incident into a GaSe crystal with the thickness of 30 μ m to generate MIR pulses with the pulse duration of less than one optical cycle [3]. The MIR beam was focused on a STM in an UHV chamber to modulate the bias voltage on the tunnel junction as shown in Fig. 1(a). The fundamental pulse of the laser was used to excite the sample of layered semiconductor of 2H-MoTe₂ ($E_g = 1.0$ eV). The result of the transient change of MIR-induced tunneling current after photocarrier excitation is shown in Fig. 2. We can see increasing and decreasing of the current with the time-scale of 220 fs and 720 fs which indicates bandgap renormalization [4]. At the delay time close to 0 fs, tunneling current due to hot-electrons show fast change of the peak-to-peak of 29 fs. This value indicate the temporal resolution of our STM which reaches to the time-scale of non-equilibrium electronic distribution. This technique will pave a new way for studying ultrafast and atomic-scale dynamics on surfaces.

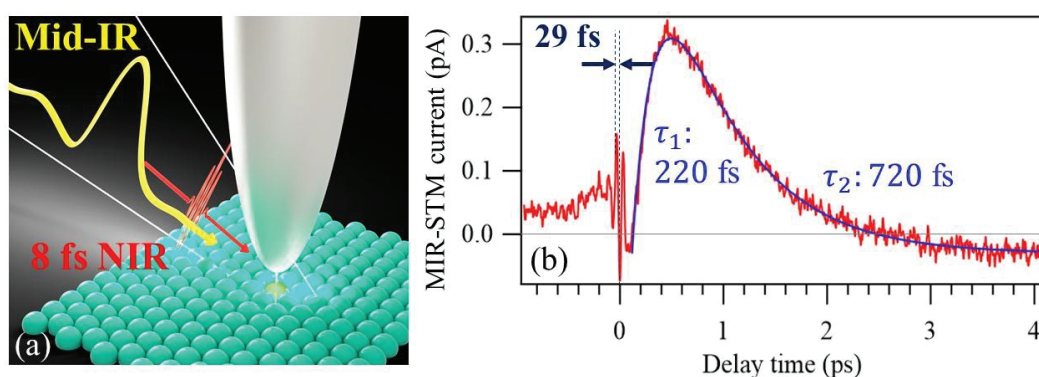


Fig. 1. (a) Schematic of 8 fs NIR-pump MIR-STM. (b) Ultrafast modulation of tunneling current in a tunnel junction of MoTe₂ and Pt/Ir tip. The pump pulses were incident at delay time = 0 ps.

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Observation of conductive holes in organic transistors using operando photoemission electron microscopy

Kosuke Yoshikawa^{1,2}, Konoha Shimizu^{1,2}, Ryoma Hayakawa²,
Elizaveta Pyatenko³, Yoichi Yamada¹, Yutaka Wakayama², Keiki Fukumoto³

¹*Institute of Pure and Applied Sciences, University of Tsukuba, 1-1-1 Tennodai, Tsukuba, Ibaraki, 305-8573 Japan*

²*Research Center for Materials Nanoarchitectonics (MANA), National Institute for Materials Science (NIMS), 1-1 Namiki, Tsukuba 305-0044, Japan*

³*Institute of Materials Structure Science, High Energy Accelerator Research Organization (KEK), 1-1 Oho, Tsukuba, Ibaraki 305-0801, Japan*

E-mail: s2520339@u.tsukuba.ac.jp

The concept of holes was introduced by Peierls in 1929 as a virtual positive charge carrier arising from the absence of an electron. Since then, the properties of holes have generally been investigated using electrical techniques such as current–voltage, capacitance–voltage, and Hall effect measurements. In this study, we introduce a high-sensitive technique; the conducting holes in organic field-effect transistors (OFETs) were visualized using operando femtosecond photoemission electron microscopy (fs-PEEM) [2].

Figure (a) shows a schematic illustration of the employed p-type OFET, where a C8-BTBT film was used as the channel layer. When applying negative gate voltage (V_G), holes are injected from the source electrode to the C8-BTBT channel and flow at the channel/gate insulator interface. Therefore, the film thickness of the channel layer is restricted in 2–3 monolayers (ML) to detect conductive holes by fs-PEEM, due to the short escape depth of photoelectrons. The obtained PEEM images of the C8-BTBT transistor at distinct gate voltages ($V_G = 0, -6.6,$ and -8 V) are presented in Figure (b). Figure (c) then indicates the V_G -dependence of the PEEM intensity (blue square dots and line), where the photoemission intensity was extracted from the same channel area enclosed by blue square lines for the different V_G in Figure (b). The variation in the drain current (I_D), which was concurrently obtained with the PEEM measurement, is also plotted in the same figure (black square dots and line). Importantly, the change in PEEM intensity well agreed with the variation in I_D , indicating the successful detection of conductive holes at the C8-BTBT/gate insulator interface. Here, the conductive holes was visualized as a reduction in the PEEM intensity. This achievement thus has the potential to provide a unique method to deeply understand the hole conduction mechanisms in versatile semiconductor devices, not only in organic transistors.

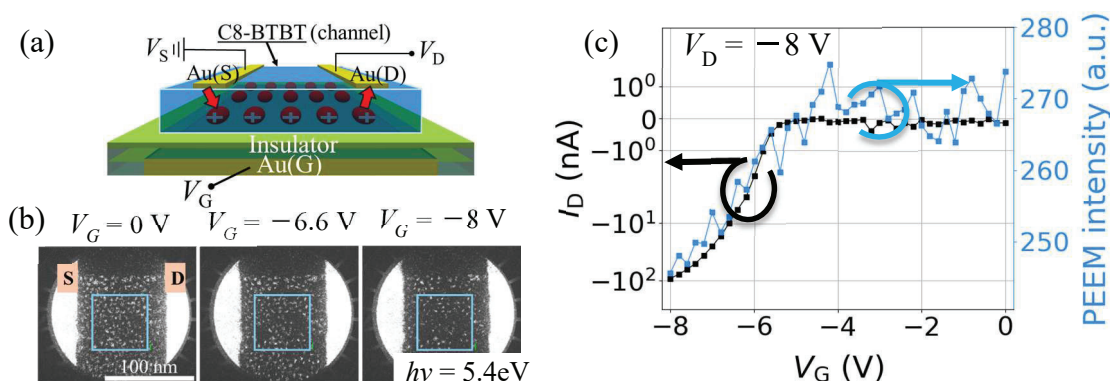


Figure (a) Schematic illustration of the p-type OFET, where 2-3 ML-thick-C8-BTBT was used as the transistor channel. (b) Operando PEEM images measured at $V_G = 0, -6.6,$ and -8 V, respectively. (c) Variations in the PEEM intensity and I_D as a function of V_G in the C8-BTBT transistor.

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SEM observation of the muscle tissue of the zebrafish line overexpressing the electric eel *egr3* gene

Tomohito Inagaki¹, Atsuo Iida², Makoto Kuwahara^{1,3}

¹ Graduate School of Engineering, Nagoya University, Nagoya, Japan.

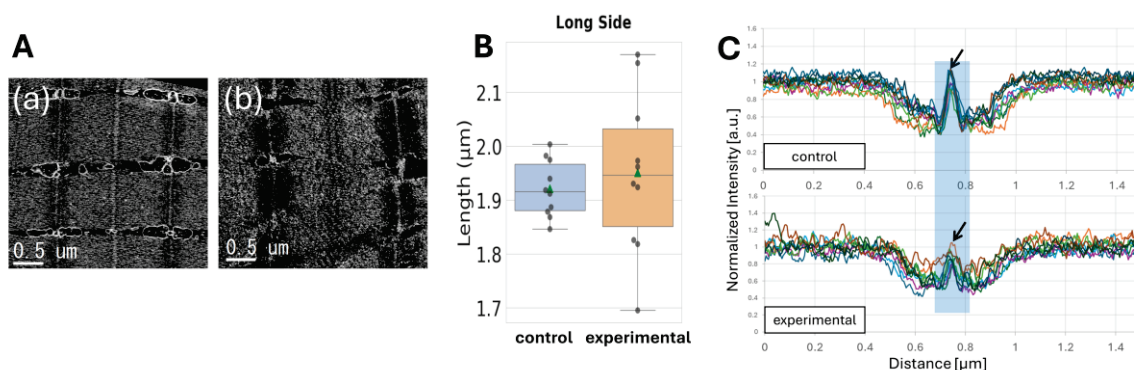
² Graduate School of Agriculture, Nagoya University, Nagoya, Japan.

³ Institute of Materials and Systems for Sustainability, Nagoya University, Nagoya, Japan

Email: inagaki.tomohito.u9@s.mail.nagoya-u.ac.jp

Electric eels generate powerful discharges from electrocytes, which are considered to have an evolutionary origin in skeletal myocytes. However, the mechanism behind this cell-type transition remains unclear. We focused on *egr3* as a candidate transcription factor responsible for electrocyte acquisition[1]. To verify this hypothesis, we generated a transgenic zebrafish line overexpressing electric eel *egr3* in skeletal myocytes and analyzed the resulting sarcomere ultrastructure using ultra-high-resolution scanning electron microscopy (SEM) in high-angle backscattered electron mode. Skeletal muscle tissues from experimental (*egr3* and fluorescent reporter) and control (reporter only) zebrafish were chemically double-fixed, resin-embedded, and sectioned into 100 nm ultrathin slices. Following double-staining with UranylLess and lead citrate, the electron images exhibiting atomic-number (Z) dependent BSE contrast were statistically evaluated. High-resolution imaging reveals that although the overall sarcomere structure is maintained in the *egr3*-overexpressing group, structural uniformity is significantly disrupted (Fig. A). F-tests indicated significantly greater variance of sarcomere length ($P < 0.01$), width ($P < 0.05$), and aspect ratio ($P < 0.01$) compared to controls (Fig. B). However, Welch's t-test shows no significant difference in mean sarcomere length (Control: 1.921 μm , Experimental: 1.951 μm ; $P = 0.569$). Furthermore, line profile analyses reveal decreased signal intensity and peak broadening at the Z-lines (Fig. C). This indicates physical degradation and density loss of the Z-line protein complexes, which act as crucial anchors for the contractile apparatus, likely causing the observed loss of uniformity.

In conclusion, SEM evaluation demonstrates that *egr3* overexpression disrupts sarcomere structural integrity in the transgenic zebrafish. These structural modifications might mimic the evolutionary transition of skeletal myocytes into electrocytes in electric eels.



Figures A-C. A) high-resolution SEM images of skeletal myocyte sarcomeres in (a) control and (b) experimental groups; B) box plot showing the distribution of sarcomere length (long axis) in both groups; C) normalized intensity profiles across sarcomeres, with black arrows indicating Z-line peaks.

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Momentum Microscopy of Gated 2D Semiconductors

Harley Suchiang¹, Sébastien Roux¹, Jacques Hawecker¹, Takumi Fukuda¹, Xing Zhu¹, Xueqi Chen², Filchito Renee G Bagsican^{1,3†}, Nanami Tomoda¹, Joanna Nadolna^{1,4}, Sathvik Ajay Iyengar^{1,5†}, Ouri Karni⁶, Suji Park⁷, Houk Jang⁷, Kenji Watanabe⁸, Takashi Taniguchi⁹, Julien Madéo¹, Michael K.L. Man¹, Keshav M. Dani^{1*}

¹ *Femtosecond Spectroscopy Unit, Okinawa Institute of Science and Technology Graduate University; Onna, Okinawa, Japan 904-0495,*

² *Department of Physics, Stanford University; Stanford, CA 94305, USA,*

³ *Research Institute of Electronics, Shizuoka University;
Johoku, Naka-ku, Hamamatsu, 432-8011, Japan,*

⁴ *Laboratory of Photocatalysis, Department of Environmental Technology, Faculty of Chemistry; University of Gdansk, 80-308 Gdansk, Poland,*

⁵ *Department of Materials Science and NanoEngineering, Rice University;
Houston, TX, 77005 USA,*

⁶ *NTT Research, Inc. Physics & Informatics Laboratories;
940 Stewart Dr, Sunnyvale, CA 94085, USA,*

⁷ *Center for Functional Nanomaterials, Brookhaven National Laboratory;
Upton, NY 11973, USA,*

⁸ *Research Center for Electronic and Optical Materials, NIMS;
1-1 Namiki, Tsukuba 305-0044, Japan,*

⁹ *Research Center for Materials Nanoarchitectonics, NIMS;
1-1 Namiki, Tsukuba 305-0044, Japan*

†Current affiliation *Email: kmdani@oist.jp

The discovery of two-dimensional (2D) semiconductors, such as monolayer transition metal dichalcogenides (1L TMDs), has heralded a new era of semiconductor research. The reduced dimensionality yields excitonic states with binding energies of an order of magnitude larger than conventional counterparts that dominate the optical response of these materials and making them an experimental testbed for excitonic physics. As such studying the material properties will be crucial for fundamental research and the development of next-generation semiconductor devices. Recently momentum microscope (MM) based angle-resolved photoemission spectroscopy (ARPES) have emerged as a powerful tool to study 1L TMDs as it offers the spatial resolution required to probe high-quality exfoliated flakes (~10 μm) with full Brillouin zone mapping that enables tracking of photoexcited carriers [1-3]. So far MM-based ARPES studies have been limited to nominally undoped samples; however, studying electrostatically doped samples will offer an additional tuning knob that will open new avenues of investigation.

In this study, we demonstrate the electrostatic gating of a 1L TMD within a time-of-flight momentum microscope setup coupled with a home-built XUV light source (21.7 eV). By tuning the applied gate voltage across the device, we can modulate the carrier density in the material. Populating the conduction band allows us to directly access the quasiparticle band gap of the material which we compare with the optical band gap measured from photoluminescence spectroscopy to extract the exciton binding energy in these materials. In the future we aim to use this platform to study momentum-resolved dynamics of photoexcited carriers in 1L TMDs in the presence of doped carriers.

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Development of a Wide-Emission-Angle Electron Gun for Performance Evaluation of an Electron Energy Analyzer

Masashi Nakamura¹, Tomoki Suzuki¹, Satoshi Ogawa^{1,2}, Hiroyuki Matsuda³, Makoto Kuwahara^{1,2}

¹ Graduate School of Engineering, Nagoya University, Nagoya, Japan,

² Institute of Materials and Systems for Sustainability (IMaSS), Nagoya, Japan,

³ Institute for Molecular Science (IMS), Okazaki, Japan,

Email: nakamura.masashi.w9@s.mail.nagoya-u.ac.jp

Auger electron yield XAFS using hard X-rays is a powerful technique for analyzing the surface chemical states and local structures of catalysts containing only a few weight percent of 3d transition metals or noble metals. Our research group is developing an electron energy analyzer for Auger electron yield XAFS. For performance evaluation of the analyzer, an electron gun is required that can simulate point-like, wide angle Auger electrons emitted from material surfaces. We therefore designed a new electron optical system inspired by the electron energy analyzer of Matsuda *et al.* [1], incorporating a rotationally elliptical mesh electrode. Electron trajectory simulations were carried out using SIMION [2] with a spatial resolution of 0.01 mm/grid. The electrode geometry and applied voltages were optimized to maximize the emission angle while minimizing the beam diameter.

The simulation results of the proposed electron gun are summarized in Fig. 1. A minimum beam diameter of 37.1 μm and a maximum emission angle of $\pm 43.57^\circ$ were achieved. Furthermore, stable focusing performance was obtained over a wide accelerating-voltage range from 1 to 13 kV, with the beam diameter remaining below 40 μm by adjusting the electrode potentials. These results demonstrate that the proposed electron gun provides stable, point-like, wide-angle electron emission and is suitable for the performance evaluation of the analyzer.

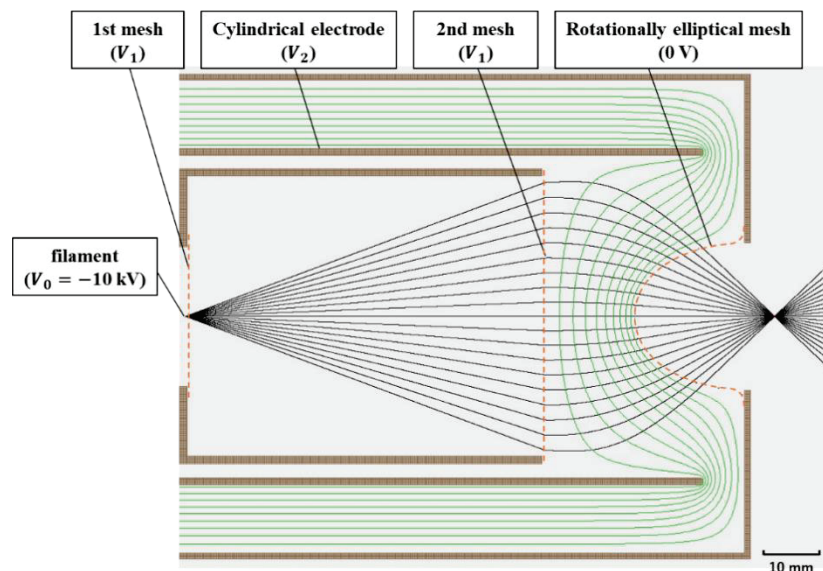


Fig. 1. Electron trajectory simulation results ($V_1 = -9999$ V and $V_2 = -9444$ V). The electron trajectories are shown in black, and the equipotential surfaces at 1 kV intervals are shown in green.

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Application of the Serial-NED Method to Time-Resolved Transmission Electron Microscopy

Takehiro Tsuchida¹, Yuki Kobayashi¹, Kotaro Yamagishi¹, Makoto Kuwahara^{1,2}

¹Graduate School of Engineering, Nagoya University, Nagoya, Japan

²Institute of Materials and Systems for Sustainability (IMaSS), Nagoya University, Nagoya, Japan

Email: tsuchida.takehiro.w3@s.mail.nagoya-u.ac.jp

Nano-beam diffraction (NBD) in transmission electron microscopy (TEM) is a highly effective technique for the structural analysis of sub-nanometer-sized crystals. Recently, a novel method called "Serial-NED" (serial nano-beam electron diffraction) was developed to analyze three-dimensional crystal structures by continuously acquiring NBD patterns[1]. This approach has a distinct advantage of being applicable to nanocrystals and thin films using TEM, and does not require the use of large-scale facilities such as X-ray free-electron lasers (XFEL). In a previous study on the structural analysis of a granulovirus, Serial-NED method achieved a resolution of 1.55 Å, surpassing the 2.00 Å resolution obtained using XFEL[1].

Our Serial-NED datasets were acquired under pulsed electron irradiation using a 100-kV time-resolved TEM (TR-TEM) [2]. In contrast to the continuous electron beam in conventional TEM, the photocathode-based TR-TEM generates pulsed electron beams. Temporal interval between two electron pulses allows for thermal relaxation, which reduces electron-beam-induced damage in the specimen.

Bis(dimethylglyoximate)nickel(II) [Ni(dmgl)₂] was used as thin-film crystal sample. The crystal structure is orthorhombic, space group *Ibam*, with lattice parameters *a*=1.66 nm, *b*=1.04 nm, and *c*=0.64 nm [3]. In accordance with the Serial-NED procedure, diffraction patterns were acquired using the TR-TEM in three steps: (i) STEM imaging, (ii) selection of the scan area, and (iii) beam scanning with diffraction-pattern recording in each position.

Diffraction patterns acquired by Serial-NED are shown in Figure 1. Figure 1(a) presents the Ni(dmgl)₂ diffraction pattern under *c*-axis incidence. In addition, off-zone-axis diffraction patterns were also obtained; as an example, Figure 1(b) shows the pattern for [0 1 29].

In conclusion, diffraction patterns acquired by Serial-NED method were successfully acquired from crystals of a metal–organic coordination complex, under *c*-axis incidence as well as for incidence directions near the *c*-axis. These results suggest that this method in the TR-TEM allows three-dimensional crystal structure analysis for other polymeric materials.

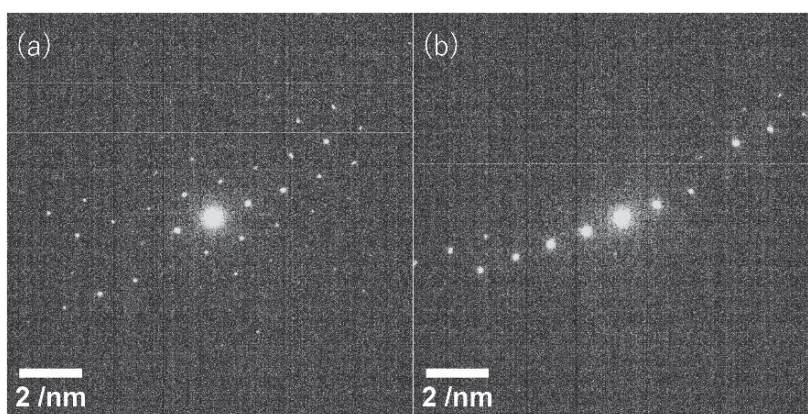


Figure 1. Diffraction patterns of Ni(dmgl)₂ acquired using Serial-NED. Images were recorded with an exposure time of 5 s at an accelerating voltage of 80 kV. Electron pulse width was 5 μs. (a) *c*-axis incidence (b) [0 1 29] incidence.

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Time-Resolved TEM Observation of Photoexcited pn-junction

Yuki Kobayashi¹, Takehiro Tsuchida¹, Toshie Yaguchi², Toshiaki Tanigaki³ and Makoto Kuwahara^{1,4}

Yuki Kobayashi¹, Takehiro Tsuchida¹, Toshie Yaguchi², Toshiaki Tanigaki³ and Makoto Kuwahara⁴

¹*Graduate School of engineering, Nagoya University, Nagoya 464-8601, Japan*

²*Hitachi High-Tech Corporation, Hitachinaka, Ibaraki, 312-8504, Japan*

³*Research & Development Group, Hitachi, Ltd., Hatoyama, Saitama, 350-0395, Japan*

⁴*Institute of Materials and Systems for Sustainability, Nagoya University, Nagoya 464-8601, Japan*

Email: kobayashi.yuki.x5@s.mail.nagoya-u.ac.jp

Carrier dynamics in a p-n junction under photoexcitation occur on a timescale of several picoseconds and influence the performance of various semiconductor devices such as solar cells and optical communication systems. However, conventional techniques has difficulty directly visualizing electromagnetic dynamics with both nanometer and picosecond spatiotemporal resolution. In this study, we aimed to directly observe the transient photo-excited reactions near a p-n junction using time-resolved transmission electron microscopy (TR-TEM)[1], which achieves high spatiotemporal resolution by generating ultrashort pulse electron beams from a semiconductor photocathode.

The sample used was a p-GaAs/n-GaAs homojunction thinned by focused ion beam (FIB) milling. To visualize the temporal evolution of the internal electric field during photoexcitation, we combined the pump-probe technique with the Fresnel method (Lorentz microscopy), which provides contrast based on the internal potential gradient. The experiment was conducted under a reverse bias voltage of 3 V and an under-focus condition. A Ti:Sapphire laser (780-nm wavelength, 150-fs pulse width, 12.5-ns pulse interval) was employed as the pump source, and the delay time between the pump and probe pulses was varied from -200 ps to +200 ps with 20-ps steps.

Analysis of the acquired TEM images revealed a bright line on the p-doped area and a dark line on the n-doped area. Electron counts on the images exhibited a dependence on the delay time. In particular, in the bright line on the p-side, the number of count began to decrease at +20 ps, indicating a reduction in the deflection angle of the electron beam due to the weakened internal electric field. This result suggests that the internal electric field is screened by changes in the charge distribution resulting from the drift of photoexcited carriers.

In conclusion, we successfully performed high-speed time-resolved observation of a biased p-n junction during photoexcitation and captured the ultrafast carrier dynamics near the junction interface. These findings will provide a deeper understanding of carrier dynamics, which will contribute to the development of more efficient semiconductor devices.

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Extraction and Analysis of Electronic Structure Information from EELS Using Bayesian Estimation

Hayato Saeki¹, Satoshi Ogawa^{1,2}, Makoto Kuwahara^{1,2}

¹ Graduate School of Engineering, Nagoya University, Nagoya, Japan

² Institute of Materials and Systems for Sustainability (IMaSS), Nagoya University, Nagoya, Japan

Email: saeki.hayato.z9@s.mail.nagoya-u.ac.jp

Electron energy-loss (EEL) peaks associated with plasmon excitations and interband transitions—both of which reflect the electronic properties of materials—are typically found in the low-energy loss region in the EEL spectrum (EELS). However, analysis of the EELS requires precise fitting to extract physical properties of specimen, because these EEL peak signals often overlap with the tail of zero-loss peak (ZLP). Conventional least-squares fitting methods, such as the widely used Levenberg–Marquardt algorithm, tend to converge to local minima near the initial parameter values due to the high sensitivity to the choice of initial conditions. Moreover, the accuracy of such methods is strongly depending on the number of fitting parameters, introducing a risk that signal noise of the spectrum may be incorporated into the fitted function.

To overcome these issues, we employed the Replica Exchange Monte Carlo (REMC) method to avoid trapping in local minima and used Bayesian free energy to evaluate the fitting accuracy in a manner independent of the number of parameters [1][2].

In this study, we performed fitting of the plasmon loss peak of Au nanoparticles using the REMC method and evaluated the fitting functions through statistical analysis based on the Bayesian free energy. As a result, we successfully extracted the plasmon-loss peak without the zero-loss peak and the background. Figure 1 shows the results of the peak separation obtained by applying the proposed method to the experimental EELS of Au nanoparticles. The low-loss peak extracted by this procedure (indicated in yellow in Fig. 1) exhibits agreement with the loss function calculated from first-principles simulations using *Quantum Espresso*. These results indicate that the approach of the REMC with Bayesian estimation is effective for extracting weak spectra that overlap with the tail of the zero-loss peak, such as plasmon excitation peaks and interband transition peaks.

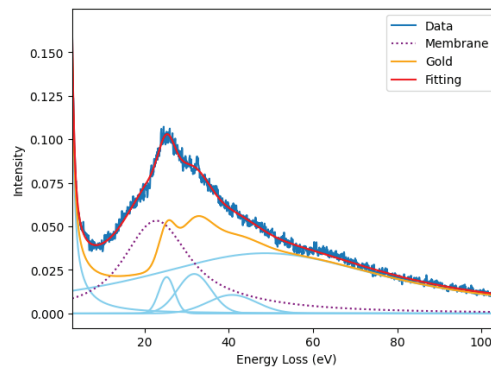


Figure 1. Fitting and peak decomposition into five Voigt functions of EEL spectrum for Au nanoparticle by Replica Exchange Monte Carlo method using Bayesian Estimation.

Acknowledgement

I would like to express my sincere gratitude to Professor Masaichiro Mizumaki and Dr. Yuichi Yokoyama for their invaluable guidance and insightful advice throughout Bayesian estimation calculations.

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Rich Electronic Reconstruction in Antiferromagnetic vdW Materials

Ryutaro Okuma^{1,2}, [Ian Lyons](#)², Yoshinori Okada²

¹*Institute for Solid State Physics, University of Tokyo, Kashiwa, Chiba 277-8581, Japan*

²*Okinawa Institute of Science and Technology Graduate University, Onna-son, Okinawa, 904-0495, Japan*

Email: i.lyons@oist.jp

Rapid progress in device engineering technology, driven by a need for downsizing, has brought significant demand for developing ‘quantum materials’ where quantum mechanics dominates physical properties on the nanoscale. The relevant phenomena are often positioned in the context of physics of strongly correlated systems, where multiple electronic degrees of freedom, such as spin, charge, and orbital, enable unprecedented competing and cooperative phenomena. Additionally, instabilities that drive these phenomena are enhanced in low-dimensional materials (quasi-2D/1D) due to phase space reduction and spatial confinement. Within this context, the realization of rich interplay between antiferromagnetism (AFM) and the metal-to-insulator transition (MIT) is one of the most promising platforms. In this poster I will report on the Angle Resolved Photoemission Spectroscopy (ARPES) measurements of GdGaI, a novel vdW AFM. In GdGaI a pronounced band deformation, indicative of an electron-hole band interaction, occurs near the onset of magnetic ordering. Strikingly, the band deformation occurs across a semi-conduction band gap suggesting the transition is not mediated by typical Fermi surface instabilities. I am planning to discuss more details in the presentation.

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Development of Terahertz Pump and Electron Probe Setup

Haruki Taira¹, Fuko Kato¹, Kaito En-ya¹, Yui Iwasaki¹, Gaël Privault¹, Arnaud Arbouet^{1,2}, Shinya Koshihara¹, Yusuke Arashida¹ and Masaki Hada¹

¹University of Tsukuba, Tsukuba, Japan

²CNRS, University of Rennes, DYNACOM (Dynamical Control of Materials Laboratory)—IRL, The University of Tokyo, Tokyo, Japan

Email: s2520307@u.tsukuba.ac.jp

Recent advances in photoinduced structural dynamics of materials and molecules have been significantly driven by the development of ultrafast X-ray and electron diffraction techniques. However, existing setups typically utilize photoexcitation for the pump beam, and reports employing alternative external stimuli are scarce. Here, we have developed an ultrafast time-resolved electron diffraction setup with terahertz (THz) wave excitation, can understand the study of ultrafast phenomena under strong electrical fields. For the THz pump and electron beam probe experiment, a desirable electron pulse duration is less than 500 fs (half cycle of THz pulse). To achieve this requirement, we incorporated a radio-frequency (RF) cavity to compress the electron pulse to longitudinal direction. Here, we directly measured the duration of the electron pulse under various conditions, utilizing an electron pulse deflection system developed with THz waves. In this system, we generated an enhanced electric field by irradiating a metal resonator with a THz pulse. The electric field deflects the electron pulse passing through the metal resonator. Consequently, the spatial extent of the electron pulse along its propagation direction, its pulse duration, was projected onto the electric-field direction, facilitating direct measurement [1]. The electric-field strength within the resonator was enhanced to approximately 700 kV/cm. Measurements indicated that the pulse duration varied with the number of electrons per pulse and the RF field strength. Pulses with high electron density ($\sim 10^5$ electrons/pulse) were compressed to approximately 400 fs (Fig. 1a), while those with low electron density ($\sim 10^4$ electrons/pulse) were compressed to less than 200 fs (Fig. 1c). Similarly, when the RF cavity was driven at 1.56 MV/m, the pulse duration was approximately 1 ps (Fig. 1d), whereas at 1.72 MV/m it was 250 fs (Fig. 1e). Beyond measurement of the duration, this setup is also applicable to THz-pump time-resolved electron diffraction. By replacing the THz resonator with a sample, it is possible to investigate the THz-driven structural dynamics of the material. The results of THz-driven dynamics of molybdenum ditelluride will be presented in the poster.

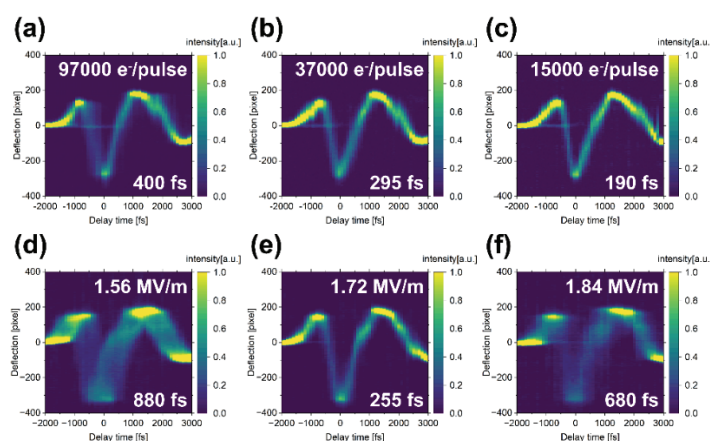


Figure 1. Figure 1 presents deflectograms measured for varying numbers of electrons per pulse: (a) 97,000, (b) 37,000, and (c) 15,000. Deflectograms corresponding to RF compression field strengths of (d) 1.56 MV/m, (e) 1.72 MV/m, and (f) 1.84 MV/m are shown, utilizing a fixed number of electrons per pulse of 23,000.

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Two-Color Microplasma-Based THz Radiation at MHz Repetition Rate

T. Hanano¹, B. S. Capanni¹, T. Fukuda¹, D. R. Bacon¹, E. Cardi², S. Skupin³, L. Bergé⁴, S. Dhillon², J. Mangeney², J. Tignon², J. Madéo¹ and K. M. Dani¹

¹Femtosecond Spectroscopy Unit, Okinawa Institute of Science and Technology Graduate University, Onna, Okinawa, Japan 904-0495, ²Laboratoire de Physique de l'École Normale Supérieure, ENS, Université PSL, CNRS, Sorbonne Université, Université Paris Cité, 75005 Paris, France, ³Université de Lyon 1 - CNRS, Institut Lumière Matière, UMR 5306, 69622 Villeurbanne, ⁴Centre des Lasers Intenses et Applications, Université de Bordeaux, CNRS, CEA, 33405 Talence, France.

Email: T.hanano@oist.jp

High-field and broadband THz radiation has enormous potential for various applications, such as THz spectroscopy, nonlinear light-matter interaction, sensing, and imaging. High-repetition-rate operation is strongly in demand because of the high signal-to-noise ratio (SNR) and fast acquisition rate. Various methods have been developed to generate THz radiation, among which the two-color plasma has the advantage of not being limited by the damage threshold. However, two-color plasma sources are typically based on mJ-class lasers operating at kHz repetition rates [1] or require extremely high average power when driven at high repetition rates [2]. We explore the use of a microplasma [3,4], generated by tightly focusing a laser to a μm -scale spot size, which enables the use of μJ -class lasers operating at MHz repetition rate to generate THz radiation.

We generate THz radiation from a two-color microplasma using a Yb: fiber amplifier (1030 nm) operated at 1 MHz with a 300-fs pulse duration and a pulse energy of 90 μJ , and the second-harmonic beam (515 nm) is generated in a BBO crystal, yielding a pulse energy corresponding to 19% of the fundamental pulse energy. Both fundamental and second-harmonic beams are focused to a 3 μm spot diameter using a concave mirror with a focal length of 5 mm, generating a microplasma (Fig.1a). We use electro-optic sampling with a 1 mm ZnTe crystal (110) to measure the THz temporal waveform (Fig.1b), showing a 3 THz bandwidth (Fig.1c). Future improvements towards high-field and broadband THz radiation will be discussed.

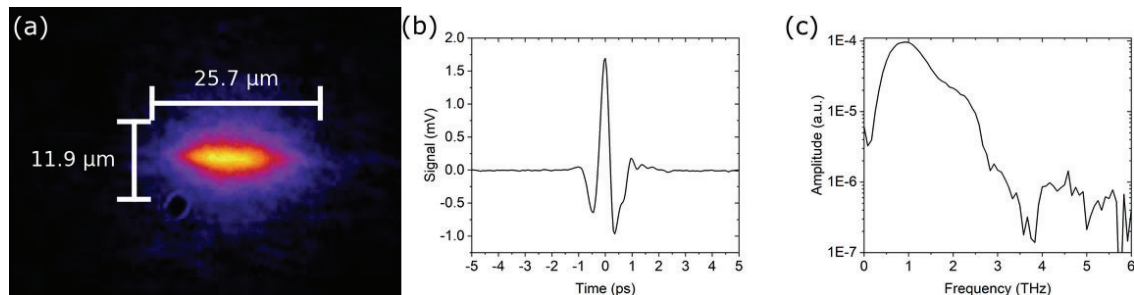


Figure 1. (a) Microplasma, horizontal size: 25.7 μm , vertical size 11.9 μm , (b) THz waveform from two-color microplasma, and (c) Fourier transformed spectrum

Acknowledgement

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Electronic structure of the skyrmion candidate materials Gd(Ru_{1-x}Rh_x)₂Si₂ studied by angle-resolved photoemission spectroscopy

N. Kanno¹, S. Huh¹, M. Kawamata², M. Ochi³, M. Hashimoto⁴, Donghui Lu⁴
Y. Dong¹, Y. Nakashima², R. Higashinaka², Y. Aoki², T. D. Matsuda², T. Kondo¹

¹ISSP Univ. of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8581, Japan

²Department of Physics Tokyo Metropolitan Univ., 1-1 Minami-Osawa, Hachioji, Tokyo 192-0397, Japan

³Department of Physics Osaka Univ., 1-1 Machikaneyama, Toyonaka, Osaka 560-0043, Japan

⁴SSRL, SLAC, 2575 Sand Hill Road, Menlo Park, CA 94025, USA

Email: nanako-kanno@g.ecc.u-tokyo.ac.jp

Skyrmion is topologically protected nanometer-scale spin vortex structures. Their controllability via electric and magnetic fields and temperature makes them promise for applications in next-generation spintronic devices. In particular, miniaturizing skyrmion and elucidating their formation mechanisms are crucial for improving information recording density and reducing power consumption. Traditionally, skyrmion formation has been considered essential for breaking the spatial inversion symmetry of crystals accompanied by Dzyaloshinskii-Moriya interactions (DMI). However, in recent years, it has been reported in which skyrmion is formed without DMI, maintaining centrosymmetry, through itinerant electron-mediated Ruderman-Kittel-Kasuya-Yosida (RKKY) interactions [1,2]. In this study, we measured the electronic structure of skyrmion candidate material Gd(Ru_{1-x}Rh_x)₂Si₂ (x = 0.025, 0.1, 0.2) by angle-resolved photoelectron spectroscopy (ARPES). The parent material, GdRu₂Si₂, possesses centrosymmetry and is known as the smallest size skyrmion. Previous studies have pointed out the importance of nesting structure as a determinant of skyrmion size through ARPES measurements [3]. Based on this finding, we investigated the changes in electronic structure when Ru sites of GdRu₂Si₂ were partially substituted with Rh and electron-doped, with the aim of controlling the nesting structure. ARPES measurements confirmed that the Fermi surface nesting vector lengthened with increasing Rh concentration, and a pseudogap, which serves as a fingerprint of the RKKY interaction at specific wavenumbers, was observed. These results provide design guidelines for skyrmion materials using fermiology.

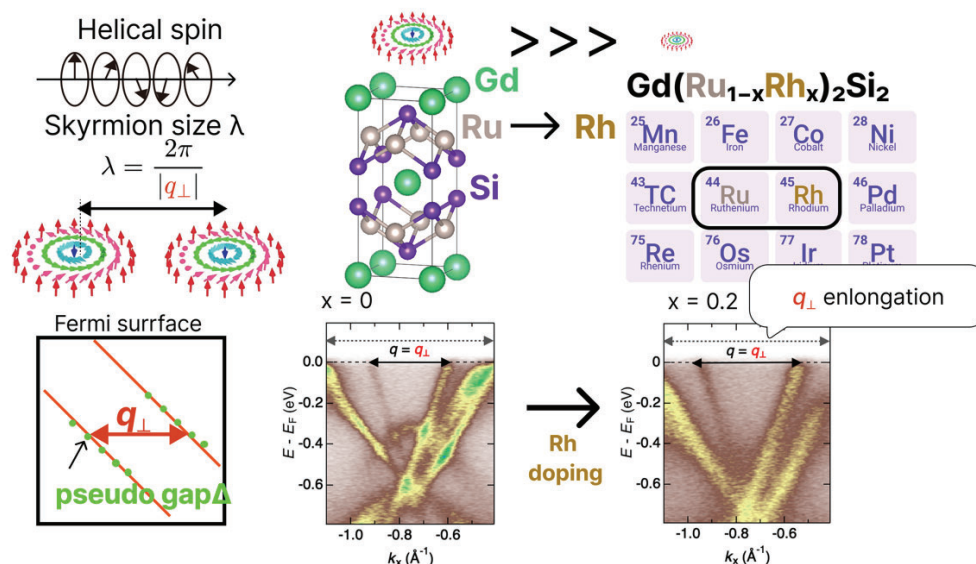


Figure 1. Expanded Fermi surface by Rh substitution and skyrmion size

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Latent image in resists visualized by laser-PEEM

Hirokazu Fujiwara¹, Cédric Bareille¹, Mario Okawa¹, Toshiyuki Taniuchi¹

¹*Institute for Solid State Physics, The University of Tokyo, Chiba 277-8581, Japan*

Email: hfujiwara@issp.u-tokyo.ac.jp

The increasing demand for further advancement and stabilization of state-of-the-art EUV lithography has heightened the importance of high-throughput inspection techniques for small patterns [1]. Direct observation of chemical patterns (latent images) formed in electron-beam (EB) and photoresists prior to development would enable rapid optimization of exposure and development conditions, significantly improving process development efficiency. Although infrared atomic force microscopy (IR-AFM) can be used to observe latent images [2], its low throughput limits its applicability in high-volume manufacturing.

We have previously demonstrated that photoemission microscopy using a continuous-wave (CW) laser light source can achieve a world-leading spatial resolution of 2.6 nm with an exposure time of 0.1 s [3]. In this study, we demonstrate that laser-based photoemission electron microscopy (laser-PEEM) enables high-throughput observation of latent images in EB resists [4]. Line-and-space (L/S) patterns were fabricated in the EB resist ZEP520A, and samples before and after development were comparatively evaluated using laser-PEEM, AFM, and scanning electron microscopy (SEM).

Laser-PEEM imaging revealed that EB-exposed regions appear as dark contrast. With optimized laser power and spot size, the throughput of latent image observation by laser-PEEM is estimated to be approximately two million times higher than that of AFM. Furthermore, for developed patterns, laser-PEEM is suggested to achieve comparable spatial resolution and signal-to-noise ratio (S/N) to SEM, while offering approximately 50,000 times higher throughput than a single-beam SEM.

In addition, laser-PEEM was shown to be capable of detecting intrinsic chemical inhomogeneities in the resist, demonstrating its utility as a chemical-state imaging technique beyond mere morphological observation. These results indicate that laser-PEEM enables pre-development inspection based on latent image observation and facilitates rapid differentiation between exposure-induced and development-induced defects. This work highlights the potential of laser-PEEM as a transformative high-throughput inspection technique for next-generation semiconductor manufacturing, and opens up new opportunities for research in latent image imaging of photoresists.

Acknowledgement

This work was supported by Hitachi High-Tech Corporation. We also acknowledge support from Oxide Corporation for the implementation of the CW laser. We thank Y. Mizuno for her technical support with the laser-PEEM measurements, and M. Oshima and T. Arima for their valuable discussions. We also acknowledge Y. Hashimoto and A. Endo for their technical support in fabricating the latent-image samples using the EB lithography in the Q-NanoLab in ISSP. This work was supported by Precise Measurement Technology Promotion Foundation and by Murata Science and Education Foundation.

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Surface Magnetization Measurement of Nb-SrTiO₃ Using PEEM

Masayuki Yamaoka¹, Cédric Bareille², Hirokazu Fujiwara^{1,2}, Toshiyuki Taniuchi^{1,2}

¹Department of Advanced Materials Science, University of Tokyo, Chiba, 277-8561, Japan

²Material Innovation Research Center (MIRC), University of Tokyo, Chiba, 277-8561, Japan

Email: yamaoka@qpm.k.u-tokyo.ac.jp

Photoemission electron microscopy (PEEM) combined with polarization-dependent measurements provides a powerful approach for probing electronic and magnetic structures at surfaces. Previous studies have demonstrated the presence of room-temperature ferromagnetic nano-domains (~40 nm) on oxygen-deficient SrTiO₃ surfaces using laser-PEEM and magnetic circular dichroism (MCD), revealing a strong correlation between oxygen vacancies and emergent surface magnetism.[1]

In this study, we extended this approach to Nb-doped SrTiO₃ (Nb-STO) surfaces and investigated in-plane anisotropy through circular and linear dichroism measurements. We observe clear rotational symmetry breaking in both circular and linear dichroism signals. By comparing these contrast mechanisms, we find that the characteristic length scale associated with surface morphology differs from that of magnetic domains, indicating that domain formation is not solely governed by surface structure but also involves electronic and magnetic interactions.

Furthermore, measurements using in-plane circularly and linearly polarized light reproduce trends consistent with previous studies, confirming the robustness of the polarization-dependent PEEM technique for detecting symmetry breaking and magnetic information at oxide surfaces.

Based on these results, we aim to apply this method to SrVO₃ (SVO), which shares a similar crystal structure, to directly probe surface magnetization. This approach is expected to provide further insight into the interplay between electronic correlations and emergent magnetism in transition metal oxide surfaces.

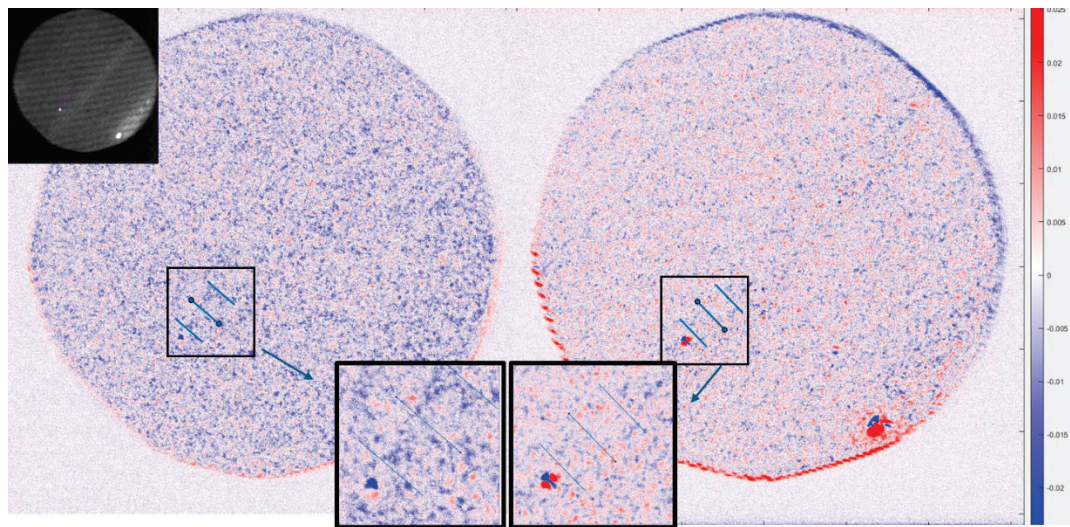


Figure 1. Nb-STO surface image acquired using a 266 nm laser (FOV: 5 μm). Top left: raw PEEM image. Left: linear dichroism. Right: circular dichroism.

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Ultrafast momentum dynamics of the transition from free carriers into excitons in monolayer WSe₂

Takumi Fukuda¹, Xing Zhu¹, Enrico Peretto^{2,3}, Jacques Hawecker¹, Harley Suchiang¹, Joanna Nadolna^{1,4}, Nanami Tomoda¹, Suji Park⁵, Houk Jang⁵, Kenji Watanabe⁶, Takashi Taniguchi⁷, Michael K. L. Man¹, Julien Madeo¹, Keshav M. Dani¹, Gianluca Stefanucci^{2,3}

¹*Femtosecond Spectroscopy Unit, Okinawa Institute of Science and Technology Graduate University, Onna, Okinawa, Japan 904-0495 .*

²*Università di Roma Tor Vergata, Via della Ricerca Scientifica 1, 00133 Rome, Italy.*

³*INFN, Sezione di Roma Tor Vergata, Via della Ricerca Scientifica 1, 00133 Rome, Italy.*

⁴*Laboratory of photocatalysis, Department of Environmental Technology, Faculty of Chemistry, University of Gdansk, 80-308 Gdansk, Poland .*

⁵*Brookhaven National Laboratory, Upton, New York 11973, USA .*

⁶*Research Center for Electronic and Optical Materials, National Institute for Materials Science, 1-1 Namiki, Tsukuba 305-0044, Japan .*

⁷*Research Center for Materials Nanoarchitectonics, National Institute for Materials Science, 1-1 Namiki, Tsukuba 305-0044, Japan .*

Email: takumi.fukuda@oist.jp

Free carriers and excitons generated in photoexcited semiconductors are crucial for understanding quantum many-body effects arising from electron-hole Coulomb interactions. In two-dimensional layered materials, such as transition metal dichalcogenides (TMDs), the weakened Coulomb screening in the monolayer limit gives rise to excitons with large binding energies (~a few hundreds meV) and strong optical absorption. Recent advancements in TR-ARPES have enabled direct observation of exciton dynamics in energy and momentum space [1,2]. However, their momentum-resolved behavior remains poorly understood despite the fundamental and technological significance of the coexistence and transition dynamics between free carriers and excitons. In this study, we investigate monolayer WSe₂ to experimentally understand the transition from free carriers to excitons in momentum space. A monolayer WSe₂ sample was mechanically exfoliated, transferred onto hexagonal boron nitride (hBN) substrates, and placed in the ultrahigh vacuum chamber with a time-of-flight photoelectron microscope. Pump pulses at 3.1 eV (above the direct transition gap) and extreme-ultraviolet probe pulses at 21.7 eV were focused onto the sample for TR-ARPES measurements. Our TR-ARPES data revealed that conduction-band populations (free carriers) emerge at energies exceeding 2 eV above the valence-band maximum at both the K and Q points upon photoexcitation. Within 1 ps, a significant fraction of these carriers transitions into exciton states at ~1.8 eV. In this presentation, we discuss the physical processes of the scattering of free carriers and excitons that govern their momentum dynamics.

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最新最先端のARPES /

Momentum Microscopyアナライザー

2D運動量マッピング光電子アナライザー ASTRAIOS 190

SPECSGROUP

特長

- $\pm 30^\circ$ ($\pm 1 \text{ \AA}^{-1}$, HeI) の光電子取り込み角
- 波数空間イメージの直接取得
- エネルギー分解能: $< 1.5 \text{ meV}$
- 波数分解能: 0.003 \AA^{-1} 、スピン分解測定オプション (Mott or VLEED)

SPC06



▲ ASTRAIOS 190



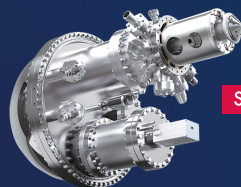
▲ VLEED

静電半球型光電子運動量分析器 KREIOS 150 MM

SPECSGROUP

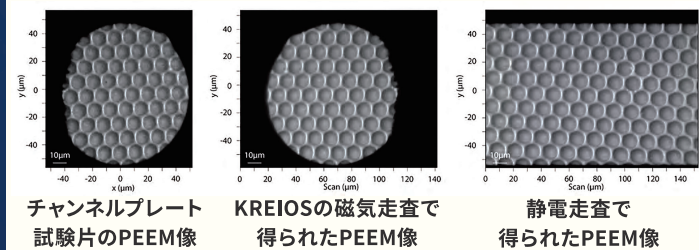
特長

- PEEMレンズ搭載
- エネルギー分解能: 25 meV (運動量顕微鏡モード)
 10 meV (スペクトロスコピーモード)
- 角度分解能: $< 0.1^\circ$
- 2Dスピン検出器 DISpin detector (オプション)
- 波数分解能: $< 0.01 \text{ \AA}^{-1}$
- 究極の取込角度: $\pm 90^\circ$



SPC07

測定例



次世代TOF型運動量光電子顕微鏡 METIS 1000

SPECSGROUP

特長

- Momentum Microscopy 測定
- k_x, k_y, kE を同時に測定 ($\Delta k < 0.01 \text{ \AA}^{-1}$)
- Parallel energy detection of ≤ 400 slices with $\Delta E < 15 \text{ meV}$
- LHe冷却型高性能顕微鏡用サンプルステージ: HESTIA
- 運動エネルギー: $0 \sim 2000 \text{ eV}$
- DISpin-Detector (オプション)

SPC05



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